THE ENGINEER SERIES

THE PRODUCTION AND TREATMENT OF VEGETABLE OILS

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INCLUDING CHAPTERS ON THE REFINING OF OILS, THE HYDROGENATION OF OILS, THE GENERATION OF HYDROGEN, SOAP MAKING, THE RECOVERY AND REFINING OF GLYCERINE, AND THE SPLITTING OF OILS

BY

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(On the Editorial Staff of "The Engineer")

WITH NINE FOLDING PLATES AND
95 ILLUSTRATIONS IN THE TEXT

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PREFACE

In this volume an attempt is made to deal with the production and treatment of vegetable oils primarily from the engineer's point of view, an aspect of the industry which hitherto has received in print scanty consideration as compared with the attention paid to the chemist's side of the matter.

Everything connected with the recovery and treatment of vegetable oils has received a great stimulus from the conditions brought about by the war. The industry is spreading or showing signs of spreading in many directions, and great as its importance in this country has been in the past, it is safe to prophesy that in the immediate future it will be greater still. It is hoped that this volume will do something towards assisting those interested or likely to become interested in the industry to understand the construction and working of the principal machines and plant which it depends upon. Sufficient information, it is believed, is given regarding the chemical and commercial aspects of the matter to make the book, although written from the engineer's standpoint, a more or less general treatise on the vegetable oil industry.

The chapters which follow originally appeared as a series of articles * in *The Engineer*. In planning this series it was at one time hoped to include in it sections devoted to certain aspects of the industrial employment of vegetable oils, notably on the employment of such oils in the manufacture of linoleum and margarine. While there is much of engineering interest in both these branches of industry it was found that a considerable degree of secrecy was preserved regarding the machinery employed in the former, while the machinery for the latter came almost, if not quite, exclusively from abroad, notably from Holland. These reasons and the exigencies of space, compelled a considerable restriction in the account of the industrial employment of vegetable oils.

On the other hand, much valuable information was obtained regarding certain aspects of the production and treatment of vegetable oils, much of which information, it is believed, has not hitherto been published, or has been published in an inaccurate, out-of-date, or incomplete form. In this connection special attention may perhaps be directed towards the sections dealing with the extraction of oils by means of chemical solvents, oil refining, oil hardening and the generation of hydrogen, the recovery and refining of glycerine, and the splitting of oils.

Sincere thanks are due to all those who so courteously afforded their assistance in the preparation of the original series of articles, particularly to Messrs. Manlove, Alliott & Co.; to Mr. H. J. Pooley, of Messrs. George Scott & Son; and to Mr. Howard Lane.

T. W. C.

London,
July, 1917.

* "The Production and Industrial Employment of Vegetable Oils." Eighteen articles. February 9th to June 29th, 1917.

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CHAPTER I

INTRODUCTORY AND GENERAL

THERE are three distinct systems or methods whereby oils in general can be classified into groups. These may be called the popular, the scientific, and the practical.

The popular system divides them into animal, vegetable, and mineral oils according to the natural kingdom from which they are derived. This scheme of classification has little scientific value, for it is more than doubtful if we are ever justified, scientifically, in speaking of a "mineral" oil. It is practically established that oil is always an organic and never an inorganic substance, and that so-called mineral oil, whether obtained direct from a well, or recovered by distilling shale, is merely the transformed product of animal or vegetable organisms. Nevertheless "mineral" oil is so distinct in its properties from either vegetable or animal oil proper that in most practical circumstances its separate classification is highly desirable. In popular phraseology, it may be remarked, "mineral" oil means petroleum, the raw product, or one of the substances derived from it by treatment. It is not usual to speak of the coal tar oils as "mineral" oils, although the well-established position of coal as a mineral would certainly justify us in doing so.

The second scheme of classification is the chemical. Into this we do not propose to enter here, for its interest is at present almost purely scientific.

The third or practical system classifies oil primarily into two groups, namely, essential oils and fixed oils. An essential oil is one which can be volatilised without decomposing it. A fixed oil is one which cannot be so volatilised. The fixed oils are further subdivided into two groups, the mineral oils on the one hand and the fatty oils on the other.

Essential oils, as we have said, are distinguished by the fact that they can be distilled without suffering an alteration in their chemical composition. They are obtained entirely from vegetable sources, commonly by distilling the leaves, flowers, fruit, or seeds of various plants. Certain barks and roots also yield essential oils, as do amber and other resinous exudations from trees. Distillation is not, however, universal, mechanical processes and extraction by means of solvents being sometimes adopted. Essential oils are used for many minor purposes. Thus the oil distilled from pine needles finds employment in the manufacture of boot polishes, while cedar-wood oil, on account of its high refractive index, is in demand for microscopic purposes. Generally speaking, however, these oils may be said to be in chief use as perfumes, as flavourings, and as medicines, typical examples of the three classes being lavender oil, peppermint oil, and eucalyptus oil.

Fixed oils, as already remarked, cannot be distilled without suffering chemical decomposition, and are divided into two groups, the mineral and the fatty. The mineral group comprises petroleum and its derivatives, and is identical with the mineral group of the popular classification. The fatty oil group, on the other hand, is not identical with the animal oil group of that classification, although it is generally true that all animal oils are fatty oils. Many fatty oils, we might even say the most important fatty oils, are of vegetable origin. Certain of the heavier mineral oil derivatives may look like fatty oils, and are used, as are some fatty oils, for lubricating and

burning purposes. Nevertheless the two classes are radically different in their chemical composition. The broad and most important and practical difference between them lies in the fact that fatty oils can be converted into soaps by acting upon them with caustic alkalis and other inorganic substances, whereas mineral oils cannot be saponified.

Fatty oils are thus either of vegetable or animal origin. Neither "vegetable" nor "animal," as here used, is, of course, to be interpreted in a restricted sense. Speaking botanically, very few oils are obtained from vegetables, the only one, in fact, which comes readily to mind being that derived from radishes, the seeds of which yield an oil of the rape or colza type. The majority of and the most important vegetable oils are extracted from the seeds of plants, for example, linseed, cotton seed, rape seed, hemp seed, poppy seed, and sunflower seed. Important vegetable oils are also obtained from the nuts of certain trees, such as the walnut, cocoa-nut, and hazel nut. Other trees yield oils from their fruit, either from the fruit itself, as in the case of olive oil, or from the fruit kernels, as in the case of cherry, apricot, plum, peach and palm kernel oils.

Speaking zoologically, the term "animal oil" is more or less justified. Thus the sheep, the horse, the ox, the whale, the seal, and the porpoise are all animals and yield important oils. It may perhaps be remarked parenthetically that the hoof of the ox is the source of the well-known neats foot oil, and that from the jaw of the porpoise there is obtained a very valuable oil used for lubricating watches and other delicate machinery. It must be admitted, however, that some important "animal" oils are recovered from fish, notably from the livers of fish. Such oils find employment chiefly in currying leather, to some extent in soap making, and to a small degree in medicine. The birds also supply "animal" oils or fats. Thus the egg of the common hen yields an oil used in leather dressing, while fats are obtained from the blackcock, duck, and goose. Even the reptile kingdom is drawn upon, for the rattlesnake gives a fat which is used in pharmacy. So far as we know the insect kingdom is not used as a source of "animal" oil. This is so presumably because of the difficulty of collecting insects in quantities sufficient for treatment, and because of the difficulty of treating them. It is certainly not due to the absence of oil in their composition. Thus, cochineal extracted with benzene can be made to yield an oil. Cochineal is, of course, the dried bodies of an insect which lives on a species of cactus cultivated, for the sake of the insect, in Mexico and Central America.

Vegetable and animal oils are frequently closely similar in composition and behaviour. Until recently it was in general impossible to determine to which class a given oil belonged solely by chemical examination. Means, however, are now available for discriminating chemically between the two classes. Thus, animal oils contain a certain alcohol known to the chemist as cholesterol. This body can be isolated from the oil recovered from sheep's wool, and is well known to the general public under the name of lanolin. A similar alcohol is contained in vegetable oils. This body is known as phytosterol. It appears to have the same molecular formula as cholesterol, but under certain circumstances it behaves differently. Thus under the microscope the crystals of the two bodies are found to be of different shape. This and the fact that their acetates melt at different temperatures form a basis for distinguishing chemically between a vegetable and an animal oil.

Apart from the existence of these two bodies in animal and vegetable oils respectively, the chemical composition of such oils cannot be regarded at present as being completely understood. This composition, of course, varies, and varies greatly, from oil to oil. Further, although to a lesser extent, it varies in any one oil according to the soil and climate in which the plant from which it was derived was grown,

or according to the age, food, even the personal habits, of the animal from which it was obtained. There need therefore be little wonder if the classification of oils on a chemical basis is, as we have stated it to be, a matter at present almost solely of scientific interest. Even in the matter of defining what an oil in general is the chemist cannot do more than adopt the popular description of an oil as a substance, usually liquid at ordinary temperatures, which is insoluble in water, combustible, and more or less viscous. This definition succeeds in that it excludes oil of vitriol—the popular term for concentrated sulphuric acid—from among the oils. It fails only in so far as it does not distinguish between an oil and a fat. There is no chemical distinction between a fatty oil and a fat. It is purely a matter of temperature, for a fatty oil when frozen becomes a fat, and a fat when melted becomes a fatty oil. A particular instance of how climate affects the nomenclature is to be found in the case of cocoa-nut oil. In India this substance is liquid, and is therefore to be regarded as an oil. In this country it is usually solid and should properly be spoken of as a fat. It has been proposed to adopt 20° C. as the standard temperature at which to judge fats and oils. The hardest fats, it may be added, melt at about 50° C., while some oils are still liquid at and below the freezing point of water.

As the title of this volume indicates, we propose to describe and discuss the production and treatment of vegetable oils. It is not our intention to deal with either essential, mineral or animal oils. The whole field is too vast to be treated conveniently in one volume, and, moreover, is not sufficiently well connected to have a common interest. In fastening our attention upon vegetable fatty oils considerations other than these have also weighed with us. Among such considerations may be mentioned the fact that these oils, particularly those suitable for edible purposes, are now attracting attention in this country to an extent hardly contemplated before the war. As is well known, Germany had in recent years become a very formidable rival to this country in its command over the vegetable oil industries, and had, as in Nigeria, for example, secured virtual monopolies over certain of the raw materials. These sources of supply have now been largely set free and, let us hope, will never again pass into our enemies' hands. Then again the war has led, as most of us know from experience, to an enormous increase in the demand for margarine, a very important outlet for certain varieties of fatty vegetable oils. Although much of this substitute for butter still comes from Holland, efforts on a gratifying scale are being made to meet the demand with margarine produced in this country.

Apart from the margarine industry, the fatty vegetable oils constitute the raw product or one of the raw products of several important industries. Thus they are used in the manufacture of paints and varnishes, soap and candles, linoleum and oilcloth. In these industries the engineer plays a very considerable part, so that both in the production and in the industrial employment of vegetable oils much of great engineering interest is to be found. It is from the engineering standpoint, and in particular from the British engineer's standpoint, that we propose chiefly to regard the matter.

In the next chapter we shall discuss the sources from which the better known vegetable oils are obtained, and the principal uses to which they are put. For the present it will be useful to describe without going into details the general methods adopted in their production.

There are two broad methods of extracting fatty oils from vegetable products—one, that employing pressure, being purely a mechanical process, and the other, that extracting the oil by means of solvents, being more or less a chemical process. Under the first method the seed, if small, is simply crushed in a hydraulic press. The oil

forced out of the seed is caught and drained off. If the seed is large or if the raw material is copra or some such stuff, it is first ground up in special machines before being crushed. The seed or seed "meal" is sometimes heated during the process of crushing. The oil then produced is known as "hot pressed" or "hot drawn" oil. Such oil, however, is apt to be unduly discoloured by reason of its having dissolved from the seed during expression an excessive amount of colouring matter. For certain purposes, therefore, notably for edible purposes, "cold drawn" oil is preferred. The "cold drawing" process usually leaves quite a considerable quantity of oil remaining behind in the seed. Consequently it is a common practice to break up the cake left in the press after cold drawing, heat it and extract a "second expression oil" by the hot process. The cake left may be once again broken up, heated, and expressed a third time, but even so it is scarcely possible to extract more than 90 to 95 per cent. of the total oil in the seed by the crushing process alone.

The second process extracts the oil from the seed or seed meal by means of chemical solvents, the seed being treated either hot or cold. The three chief solvents in use are benzene, carbon disulphide, and carbon tetrachloride. The process in outline consists of allowing the solvent to percolate through the seed or meal in a closed vessel, draining off the solvent and dissolved oil, transferring it to a heated still and there driving off the volatile solvent so as to leave the oil behind. The solvent is condensed and re-used.

So far as the percentage of oil recovered from the seed is concerned, this process is distinctly superior to the pressure process, for under it as much as 99 per cent. of the oil can readily be extracted from the raw material. A further advantage of the process undoubtedly lies in the simplicity and cheapness of the plant required as compared with that used under the pressure method.

The relative advantages of these two processes form a subject of much discussion. As the reader is doubtlessly aware, the residue left after the oil has been extracted from linseed, cotton seed, copra, and certain other oil-bearing substances, is in great demand as a cattle food. While it is admitted generally that the solvent extraction process recovers the oil more thoroughly from the seed, etc., than does the pressure process, it is frequently urged that its very efficiency in this respect deprives the residue of much, if not quite the whole of its value as a feeding stuff. The 5 to 10 per cent. of oil remaining in the cake left after crushing in a press is not, it is claimed, a source of loss, for without it the residue could at best command a market only as manure. On the other hand, it is stated that the oil left in the cake is only a heat-forming substance, and that the husks, etc., of the seed form the real food value of the cake. Further, oil press cake, it is argued, cannot be fed undiluted to cattle, but has to be mixed with bran and other substances, a fact which would seem to imply that oil cake is a richer food than it need be. The residue left by the solvent extraction process retains all the husks, etc., while its richness in oil is not such as to prevent its being fed directly to cattle.

Whatever may be the true way of looking at this matter we have next to note that the advocates of the pressure system urge a further objection to the solvent extraction process. This is to be found in the alleged difficulty or impossibility of getting rid of the last traces of the solvent used either from the oil or the residue. The point is of importance, for the solvents commonly used are either poisonous or have a nauseous taste. If the allegation were well founded, therefore, solvent extracted oils could not be readily used for edible purposes, and would have to find an outlet solely in industrial applications, such as soap making, while the residue would probably be refused as food by cattle and would have to be used as manure.

Whatever may at one time have been the case, and may still be where old-fashioned

German-made solvent extraction plant is in use, it seems certain that recent progress has overcome these objections to the process. We are credibly informed that horses and cattle will eat extracted meal with avidity. We have examined oil extracted with benzene, and neither to the taste nor smell did it reveal any trace of the solvent, although benzene is said to be the most difficult of all the solvents to eliminate.

It is advisable, we think, to discard the idea that the two processes are essentially rivals. It is certainly undoubted that they can be very profitably worked side by side in the same mill, for the solvent process can be made to supplement the pressure process frequently with great advantage. Thus certain seeds can profitably be crushed to recover a high-class edible or other oil, and thereafter treated with solvents to recover the remaining oil. It is to be noticed that in discussing the relative advantages of the two processes it is not wise always to confine our argument to the general case. Our conclusions must be modified not only by local conditions as to the outlet for the oil and seed residue—that is, the press cake or extracted meal—but also by the particular oil-bearing seed which is to be treated. Thus the residue of certain seeds, rape seed, for example, has little or no value as a foodstuff however it is obtained. It seems, therefore, only reasonable in such cases to adopt that process which recovers most oil from the seed, and which, moreover, leaves the residue in a form which is directly suitable for manurial purposes. On the other hand, the solvent extraction process should be studied cautiously if castor seeds are in question. Castor oil is in several respects an exceptional oil and appears to suffer some chemical change by the action of solvents.

In conclusion, it may be remarked that any objection to solvent extracted meal as a foodstuff on the ground that it is deficient in oil can be overcome by mixing it with the desired proportion of oil and moulding it into cakes. Again, it can be mixed with ground-up press cake and the whole remoulded. Both practices are followed on the Continent. We may add that so far as we can discover there is no ground for the assertion made in an authoritative work that extracted meal cannot be sold in this country as a cattle food.

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The relative advantages of these two processes form a subject of much discussion. As the reader is doubtlessly aware, the residue left after the oil has been extracted from linseed, cotton seed, copra, and certain other oil-bearing substances, is in great demand as a cattle food. While it is admitted generally that the solvent extraction process recovers the oil more thoroughly from the seed, etc., than does the pressure process, it is frequently urged that its very efficiency in this respect deprives the residue of much, if not quite the whole of its value as a feeding stuff. The 5 to 10 per cent. of oil remaining in the cake left after crushing in a press is not, it is claimed, a source of loss, for without it the residue could at best command a market only as manure. On the other hand, it is stated that the oil left in the cake is only a heat-forming substance, and that the husks, etc., of the seed form the real food value of the cake. Further, oil press cake, it is argued, cannot be fed undiluted to cattle, but has to be mixed with bran and other substances, a fact which would seem to imply that oil cake is a richer food than it need be. The residue left by the solvent extraction process retains all the husks, etc., while its richness in oil is not such as to prevent its being fed directly to cattle.

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linseed oil available for burning and lubricating purposes. Its quick drying properties, however, render it unsuitable for these uses, particularly for the latter.

Cotton Seed Oil.

Several oils have claims to be ranked next in importance to linseed oil. One of these is cotton seed oil, as obtained from the seeds of the cotton plant. There are several varieties of cotton plant, such as the Upland and Sea Island varieties, as grown in the United States, and the Egyptian, Indian, Brazilian, and Peruvian. The fruit or "boll" of the plant, when ripe, bursts open and exposes the cotton in the form of a fluffy mass. In this condition it is gathered and is known as seed cotton, for it consists of about one-third by weight of fibre and two-thirds of seed. The fibre is attached to the seeds and has to be separated therefrom in a cotton gin. The degree of success attending the ginning is an important consideration in the subsequent recovery of the oil from the seeds. The Egyptian plant yields a black seed, from which the fibre is easily removed completely in the gin. The American and Indian seeds, on the other hand, are white and leave the gin with a considerable amount of the fibre still adhering to their husks. Such seeds are sometimes reginned in the mill before being further treated. Practice differs, however. In some cases the seeds are crushed as received, the fibres and husks being allowed to pass into the cake. In other cases, as, for example, very frequently in the case of American "Upland" seed, the fibre is removed, the husks are taken off in a decorticating machine, and the kernels, or "meats" as they are called, are alone crushed. The seeds on the average consist of 60 per cent. kernel and 40 per cent. husk. The amount of oil which they contain varies from 18 to 24 per cent., according to the country and plant producing them.

Cotton seed kernels, the real source of the oil, contain a strong deep-brown colouring matter. Owing to the difficulty of refining the crude oil, the seed not required for planting was, until a little over sixty years ago, thrown away, although as long ago as 1783 the Royal Society of Arts endeavoured to encourage the production of cotton seed oil and cotton seed cake. In America, up to 1860, the disposal of the seed from the ginning plant was, in fact, a problem of no little concern to the proprietor. He was heavily penalised if he allowed the seed to accumulate near the gin, and was strictly forbidden to get rid of it by throwing it into any river or stream. The waste seed was to a small extent used as a manure, but the bulk of it had to be burned. Later on it was discovered that the residue left after milling the seed for its oil retained all the fertilising properties. Cotton seed meal, that is, the press cake ground up, is still largely used as a manure for sugar cane, cotton, corn, tobacco, and so on. It is now, however, realised that the most economical manner of using it is to feed it to cattle and to use the resulting manure, which retains 80 to 90 per cent. of the original fertilising value, on the ground.

Cotton seed oil is a so-called semi-drying oil. It absorbs oxygen slowly under ordinary conditions, but by blowing air through it at about 100° C. the absorption can be increased. Blown cotton seed oil and other semi-drying oils similarly treated become thickened and appear in density and viscosity like castor oil. They are produced on a considerable scale and when dissolved in light mineral oils are used as lubricants. Refined cotton seed oil is in extensive use for edible purposes. It appears on the table as salad oil, it is used by the sardine tinning industry, and under the name of butter oil it forms one of the chief raw materials of the margarine manufacturer and of the manufacturer of lard substitute, or compound lard as it is called. Apart from the very great use of cotton seed oil for edible purposes its chief industrial employment is in the soap-making industry. It is frequently used in this connection by itself. As an

ingredient of toilet soap it is commonly mixed with tallow or cocoa-nut oil. It is also widely used in the manufacture of soap powder.

Olive Oil.

Olive oil is in several respects chemically and industrially closely similar to cotton seed oil. The latter being cheaper is frequently substituted for it, notably for edible purposes. The reputation of olive oil as an edible oil is, however, too great for it ever to be supplanted completely by any other. The olive tree is chiefly cultivated in the countries bordering the Mediterranean. Recently attempts, not always with success, have been made to grow it in India, California, South Africa, and Australia. The fruit of the olive consists of rind, flesh, stone, and seed kernel. All parts contain oil. The fleshy part, forming 80 per cent. of the whole, contains from 40 to 60 per cent. of oil and yields the best oil for edible purposes. To produce this oil the fruit is gathered before it is quite ripe and is peeled and stoned. The flesh is then pressed by itself. The kernels are crushed separately and yield an inferior "olive kernel oil." The pulp left after the pressing of the flesh may contain as much as 20 per cent. of oil. It is ground up with hot water and allowed to stand until the broken up cellular tissue rises to the surface. This is again pressed for a second quality oil. The residue is finally extracted with solvents, commonly carbon disulphide. Such extracted oil acquires a deep green colour from the chlorophyll in the fruit, and is principally used for soap-making. In some mills the original fruit is not stoned before being pressed for the first time, but is crushed as a whole. The oil yielded is of a less perfect quality than that obtained by the other process, for it contains the poorer oil derived from the kernels.

The oil derived from the first pressing of the fruit is almost invariably used for edible purposes. A second or third pressing is commonly adopted. The oil so obtained is used for soap-making and for lubricating and burning purposes, for olive oil is a non-drying oil. The press cake is sometimes used locally as a cattle food. The value of the oil, however, makes it pay to carry the recovery to the greatest possible extent. Hence the last drop of oil is usually recovered by the chemical solvent process and the residue sold as manure.

Castor Oil.

The castor tree or shrub—it is found in both forms—grows in all tropical and sub-tropical countries. The seeds are enclosed within a rough outer shell or pod, and themselves consist of a husk containing a white soft kernel. The kernel forms 80 per cent. of the seed and yields from 46 to 53 per cent. of its weight in oil. The husks are oil-less. The bulk of the seed used in commerce comes from the East Indies.

Castor oil is of the non-drying class and is of great value as a lubricant. It is extensively used in the soap industry. Treated with concentrated sulphuric acid it yields a fatty substance known as Turkey Red oil, which is used in preparing cotton fibre for dyeing in the Turkey Red industry. Its medicinal use depends upon the fact that it contains an alkaloid. This alkaloid in excess is poisonous, and as it is retained in considerable quantity in the residue left after crushing the seeds, castor oil cake is unfit for a cattle food. Consequently it is extracted with solvents to recover a quality of oil suitable for soap-making and other technical purposes. The ultimate residue is used as a manure.

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of the chief articles of food for the inhabitants. Nevertheless, the bean and the oil it yields were almost unknown in Europe until the Russo-Japanese War. Since then the production and use of soya bean oil and soya bean cake have developed phenomenally. The oil in Europe now rivals that obtained from the cotton seed, while the cake, on the Continent at least, is contesting the position as a food for milch cows held by linseed and cotton seed cake. The oil belongs to the semi-drying class, and is used for edible purposes, as an illuminant, in soap-making, and in the manufacture of linoleum. The bean contains about 18 per cent. of oil, and in the press yields from 10 to 13 per cent.

Rape or Colza Oil.

The rape plant is grown extensively in many European countries, notably in Russia. It is cultivated in British India to an extent which renders the annual crop second only in importance to the linseed crop. The bulk of the Indian seed is shipped to England, but Germany used to have a preponderating hold on other sources of supply. Rape oil belongs to the semi-drying class, and is principally used for burning purposes and as a lubricant. In the latter case the oil is frequently "blown," as mentioned above under cotton seed oil. To a small extent rape oil when obtained by "cold drawing" is used for edible purposes, notably by bakers in the production of bread. It is commonly employed as a quenching medium for steel plates, etc., and on the Continent is used occasionally in the manufacture of soft soap. The seed contains anything from 33 to 43 per cent. of oil. It is frequently extracted by means of solvents. The oil apparently contains a poisonous element. Consequently rape seed cake is not greatly valued as a cattle food. It may, in fact, be said that the bulk of the residue left after either crushing or extraction with solvents is used as a manure.

Mustard Oil.

This oil is obtained from the black, white, or wild mustard plant, and is used in soap-making and as a substitute for or adulterant in rape oil, to which it is closely similar. The cake left after crushing is, however, a more important product than the oil. When ground this cake gives the mustard of the domestic table.

Sunflower Oil.

The sunflower is cultivated for the sake of its seeds on an immense scale in Russia, Italy, India, and China. The seeds, raw or roasted, are used in Russia as an article of diet. The oil recovered from them by crushing is, when refined, considered by some to equal olive oil for edible purposes. Its chief use, however, is in soap and candle-making. The seeds contain from 20 to 23 per cent. of oil. For cattle-feeding purposes the cake is not only very palatable, but being rich in nitrogenous matter is of great food value. Sunflower oil belongs to the drying class. The sunflower is very readily cultivated, and produces a high yield of seeds. It is believed that the Central Empires, cut off as they are at present from many important sources of oils and fats, are cultivating the sunflower on an extensive scale in an attempt to reduce the deficiency. They are probably growing flax—for linseed oil—also on a considerable scale, but flax, it is to be noted, rapidly exhausts the soil and is therefore in all likelihood being cultivated to an extent only slightly greater than in peace time. It may perhaps be added that the rumours recently in circulation as to Germany's shortage of glycerine and the horrible means she is adopting to make it good cannot be accepted as true by those qualified to judge. In the first place Germany uses little or no glycerine in the production of her explosives, differing in this respect from this country, which, of

course, depends extensively upon nitro-glycerine. In the second place the yield of glycerine from the source suggested would be altogether too insignifican to justify the cost, trouble, and difficulty of recovering it.*

Poppy Seed Oil.

The seed of the poppy contains from 45 to 50 per cent. of an oil which, when "cold drawn," is almost colourless, has little odour, and possesses a pleasant taste. It is in extensive use on the table as a salad oil, and is highly valued by artists and artists' colourmen. The seeds are usually expressed twice, the second pressing being carried out hot and yielding an inferior oil which is extensively employed in making paints and soft soaps. The oil belongs to the drying class. Poppy seed cake is rich in nitrogen and is highly valued as a cattle food.

* Since these remarks were written, the rumours referred to have become a popular article of belief, in this country at least, and have received what would appear to be semi-official confirmation.

CHAPTER III

PREPARATORY MACHINERY FOR COPRA AND LINSEED

From the engineering point of view the machinery and plant used in the production of vegetable oils may conveniently be divided into four classes. First we have what may be called the preparatory machinery, the plant, that is to say, which deals with the seeds, nuts or fruit as received from the growers, and reduces them to a form suitable for treatment in the subsequent oil recovery processes. Next we have the presses wherein the material so prepared is crushed. Thirdly, there is the plant employed when the oil is extracted by chemical solvents, either as an alternative to crushing or as supplementary thereto. Fourthly, there is the plant employed to refine the oil. To these four classes ot oil mill machinery and plant a fifth has to be added. This is not so much concerned with the production of the oil as with the production and treatment of the cake.

Of the machinery in the preparatory class it may be said that there are three distinct divisions. In the first of these we have the machines and appliances used in the separation of the oil-bearing portion of the natural product from the non-oil bearing portions, or from secondary oil-bearing portions which it is desired to treat apart from the first. The portions thus separated have in general to be prepared for the presses by crushing, shredding, and otherwise reducing them to a meal of sufficient fineness to present the minute oil vesicles in the best form to the action of the press. The machines thus employed form the second of our three divisions. The third division embraces machines and appliances concerned with the manipulation of the meal just before it goes into the press. These manipulations include the heating of the meal to a suitable temperature and its rough moulding into slabs or cakes for insertion within the press. It will be understood, of course, that this is a general outline only, and that all oil-bearing vegetable products do not necessarily require the whole run of the appliances thus indicated. Thus linseed, rape seed, and similar small seeds do not entail the use of any preparatory machines of the first division. On the other hand, cotton seed frequently, and palm kernels nearly always, require the use of machines of all three kinds. The machines of the first division are in general of a specialised nature, that is to say, they are in most cases each designed to deal with one particular class of seed. The machines of the second division are very similar among themselves whatever the seed or nut being treated. The machines of the third division do not vary with the nature of the seed being dealt with, for by the time the seed reaches them it has lost all its outstanding original physical features, and whatever it was to begin with is now in the form of more or less fine meal.

We now pass to a description of the more or less specialised preparatory machinery in use or designed for the treatment of certain important oil-bearing substances. Before doing so we desire to make two general remarks which may avoid occasion for misunderstanding. In the first place certain of the machines described below are suitable for treating substances other than that mentioned in the heading under which they appear. Secondly, the fact that any given machine is mentioned as being made by such and such a firm does not necessarily mean that it is made only by that firm.

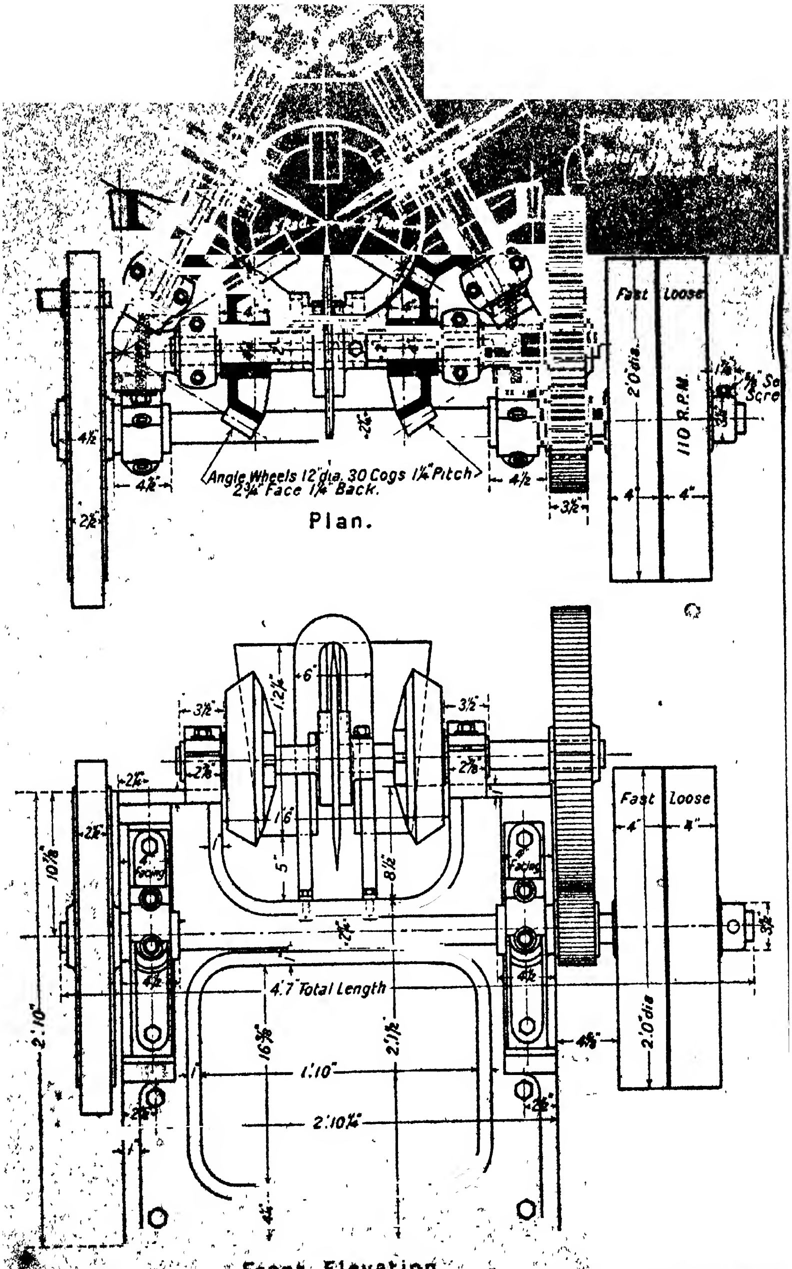


FIG. 1.—Cocoa-nut Splitting Machi

Preparatory Machinery for Copra.

The cocoa-nuts as gathered have first to be split open. The split nuts are then set in the sun, placed in a kiln, often of rude construction, or, as is now becoming the practice, deposited in a lightly built galvanised iron house beneath the floor of which steam-heating pipes are disposed. In either of these ways the moisture contained in the flesh of the nut, amounting to about half the original weight of the flesh, is driven off and the flesh itself becomes loosened from the shell. The dried flesh—copra—is then exported. Great care is necessary in carrying out the drying process, for the material can readily be spoilt by attempting to drive off the moisture too rapidly, with the result that the flesh is discoloured and the oil recovered from it is difficult to refine. On the other hand, the natural moisture in the flesh must not be allowed to remain unduly long in contact with the oil in the flesh after the nuts have been split. If this is permitted the water will hydrolise the oil, that is to say, it will enter into chemical combination with it and split it up into two elements, namely, glycerine and free fatty acid.

The splitting of the nuts was, and still is, frequently performed simply with a hammer. More scientific means are now, however, being introduced. In Fig 1 we give the general arrangement of a machine for the purpose made by Rose, Downs & Thompson, Ltd., of Hull. This machine deals with nuts as gathered, that is to say, it treats them with their outer husks still on. By means of three circular knives having saw-like teeth, and spaced at 120 degrees apart, it cuts through husk, shell, and kernel, and divides the whole into three parts. The knives are mounted on three shafts forming a triangle in plan, and geared together by bevel wheels. One of the knife shafts is driven by spur wheel and pinion from a belt-driven countershaft carrying a flywheel. The knives are 1 ft. 5 in. in diameter and run at about 25 revolutions per minute. A more or less conical sheet metal hopper is fixed over the knives. The knives pass through openings in the sides of this hopper. Three bent plates or knees are attached to the inside of the hopper to act as guides for the nuts and lead them to the centre of the hopper. There they are caught by the knives and are cut and carried downwards to fall on to the base plate of the machine. About 2 h.p. is required to drive this machine. Its output may be returned at 2,000 nuts per hour. It will, in fact, split the nuts as fast as one man can feed them to it.

The copra as received at the oil mill in this or some other country is in the form of lumps of considerable size. These have to be reduced to the form of " meal " by various shreddings and grindings. Before doing so, however, it is necessary closely to examine the material, for it is frequently found to contain an odd assortment of scrap iron, such as hammer heads, bolts, nuts, horseshoes, nails, etc. The native and other gatherers of palm nuts, copra, and so on, are paid by weight, and on occasion do not scruple to turn a dishonest penny. Many breakdowns of machinery have been caused by the undetected presence of such foreign matter in the material treated, particularly so in the case of mills handling copra and other substances which as part of the preparatory process have to be ground. To remove the objectionable substances resort is commonly made to hand picking the material before anything else is done to it. This process is slow and monotonous, so that it is not surprising that modern practice should call for some mechanical means of performing the operation.

An appliance of this nature, a magnetic separator, made by Rose, Downs & Thompson, Ltd., is illustrated in Fig. 2. The material to be treated is delivered on to a sloping sheet metal tray supported on four flexible spring rods A and rapidly vibrated by means of a connecting rod B, and short-throw crankshaft C. The shaking

action of this tray distributes the material uniformly, and further causes the heavy iron ingredients to sink by gravity to the bottom of the batch. Sometimes the tray

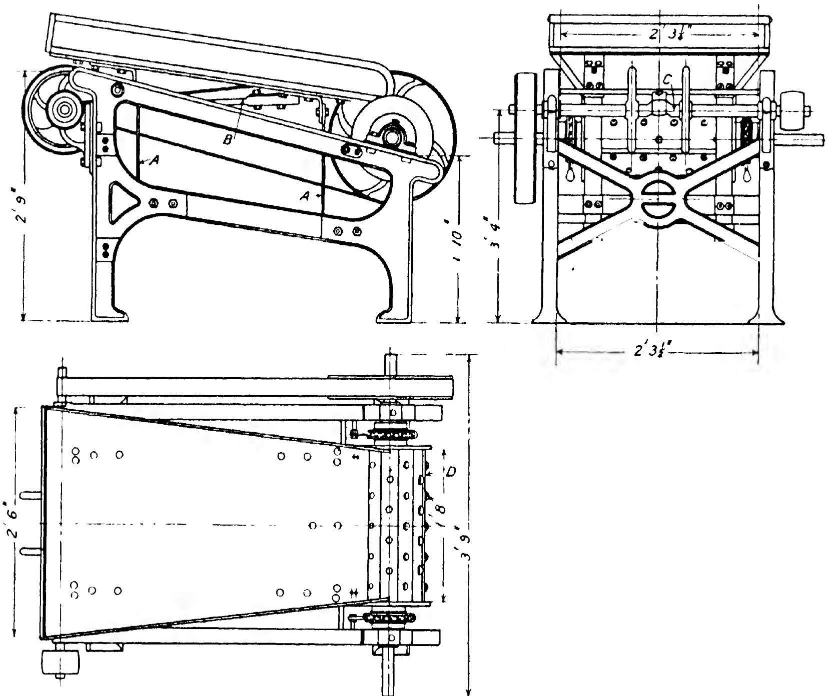


Fig. 2.—Magnetic Separator for Copra, etc.—Rose, Downs & Thompson.

can be made in the form of a screen, when it will serve the additional purpose of separating any fine impurities, sand, chips, and so on, from the oil-bearing substance.

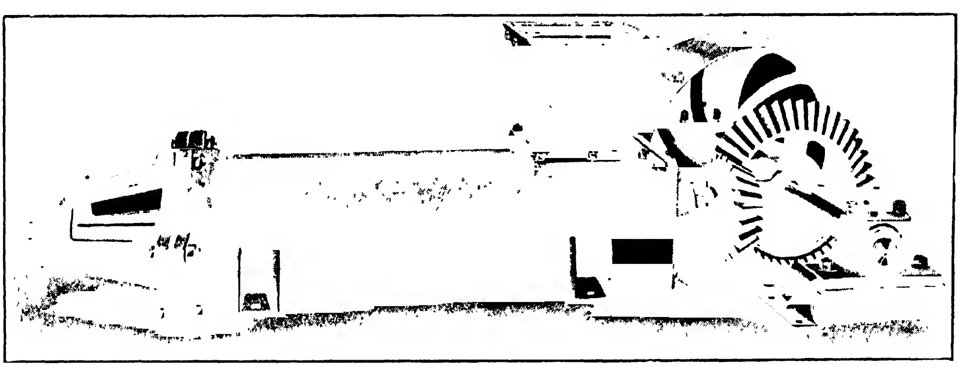


Fig. 3.—Preliminary Breaking Machine—Manlove, Alliott.

The material leaving the tray falls on to a power-driven magnetic barrel D, provided with several rows of studs, each row being mounted on a separate commutator section of the barrel. The non-magnetic material is carried round the barrel and drops off

at the front into a suitable hopper. The iron intruders are carried round to the back until they reach a point at which the section of the barrel to which they are adhering is automatically demagnetised for a moment to permit them to drop off. The size of machine illustrated has an output of from 1 to $1\frac{1}{2}$ tons per hour. It is driven from the small pulley at the end of the shaker crankshaft, which shaft is rotated at 300 revolutions per minute. About a horse-power is absorbed in driving the machine. The current required for the magnetic barrel is 7 amperes at 40 volts, and can be conveniently supplied by a small belt-driven dynamo provided for the purpose.

Machines for Reducing Copra, etc

The reduction of copra as imported to the form of meal for the press requires special consideration The copra is generally received in pieces of such a size that it has to be reduced in three, four, or even five separate stages. Usually these reductions are effected by means of rolls. For the first reduction, however, rolls may be dispensed

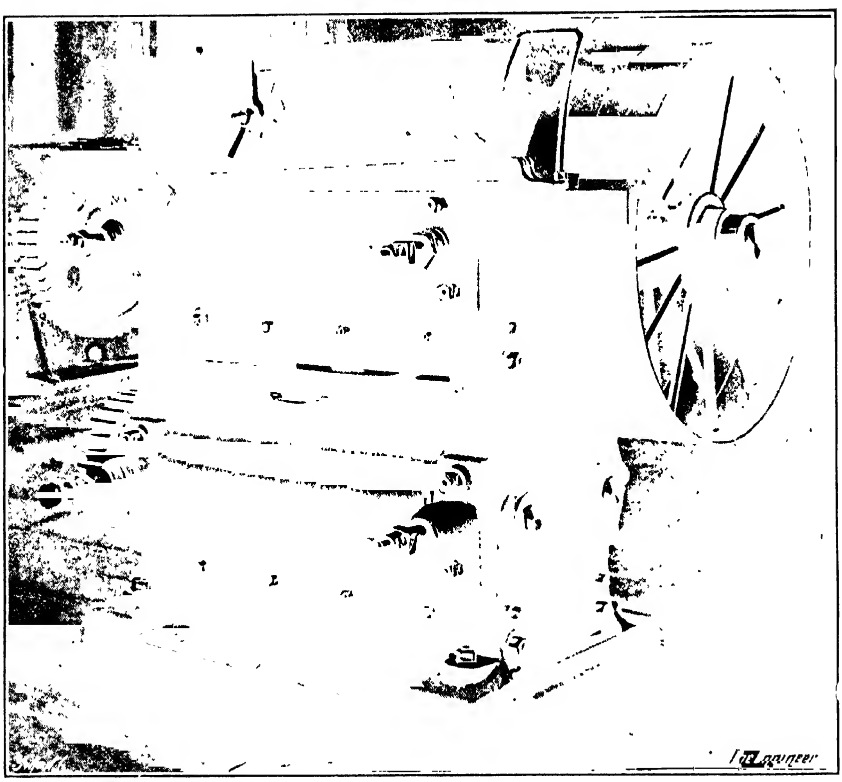
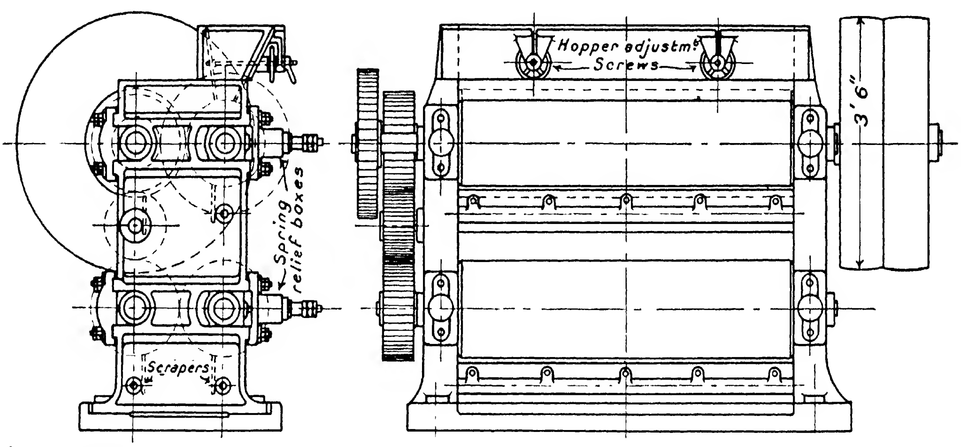


Fig. 4.—Shredding and Crushing Rolls for Copra, etc A. F. Craig.

with and a preliminary breaking machine, Fig. 3, as made by Manlove, Alliott & Co., Ltd., of Nottingham, used in their place. This machine is claimed to be considerably cheaper than rolls both in first cost and in maintenance, and to run without attention so long as it is fed evenly. The casing of the machine is a cast-iron barrel ribbed internally to prevent the copra rotating as a mass within it. The casing contains a power-driven segmental worm having a coarse pitch at the feed end and a finer

pitch at the delivery end. At the latter end there is fitted a hardened perforated steel plate through which the partially broken copra is forced by the worm. A four-bladed knife revolves against the worm side of this plate and cuts the copra as it passes through the perforations besides assisting its passage through these holes. The worm shaft is fitted with Hoffmann ball thrust bearings. The perforated plate can be readily changed and one with smaller holes substituted for it. This change permits of the machine being used with equal facility for the breaking of palm kernels.

The material as thus disintegrated is next reduced a step further by means of rolls which shred and crush it. A set of rolls suitable for this purpose, as made by A. F. Craig & Co., Ltd., of Paisley, is illustrated in Figs. 4 and 5. The example here represented has two pairs of rolls, the upper pair of which is fluted longitudinally, the lower pair being plain. The rolls, as is usual, are of chilled cast iron and are



"THE ENGINEER" SWAIN SC.

FIG. 5.—Shredding and Crushing Rolls—Craig.

hydraulically pressed on to steel shafts. One roll in each pair runs in fixed bearings, the other running in sliding bearings which are acted upon by relief springs disposed within circular boxes on the frame sides. The force of these springs is adjustable to give the required degree of pressure between the rolls. In a common size of machine, one capable of dealing with 15 cwt. of material per hour, the rolls are 48 in. long. The lower rolls are each 14 in. in diameter, and run at about 130 revolutions per minute. The upper rolls are of different diameters and rotate at different speeds. The larger roll is 16 in. in diameter, and runs at about 110 revolutions per minute, the smaller roll being 12 in., and running at about 47 revolutions. The peripheral speed of the larger roll is thus about three times that or the smaller. As a result, the partially reduced material falling from the hopper between the top rolls is shredded by the fluted surfaces. Falling between the plain lower rolls it is still farther reduced by a crushing action. Each of the four rolls is provided with a scraper working against its lower portion. The feed hopper consists of a trough formed over the smaller of the two top rolls. At the front a fixed plate extends from it to the surface of the roll. At the back a hinged plate, adjustable by means of one or two screws and hand wheels, permits the quantity of material passing out of the hopper to be regulated. About 15 b.h.p. is consumed in driving a set of rolls of the size mentioned in this paragraph.

A set of rolls made by Manlove, Alliott & Co., Ltd., for the same purpose as the above is represented in Fig. 6. In this case there are three pairs of chilled cast-iron rolls. All six are of the same size, each being 15 in. in diameter and 36 in. long The two top pairs are spirally fluted and are driven from the belt pulley at the right-hand end of the machine through double helical gearing. The two rolls in each of these

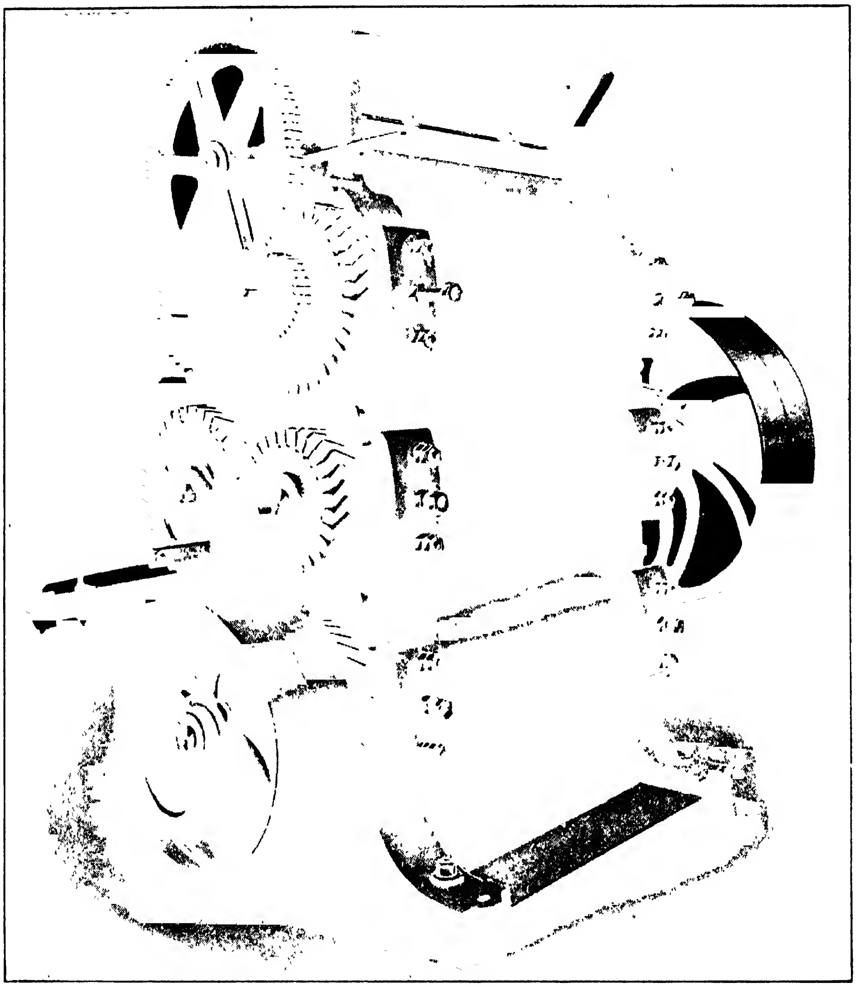


FIG. 6.—Rolls for further Reduction of Copra—Manlove, Alliott.

upper pairs rotate at different speeds so that the action is a shredding and grinding one. The two lower rolls are plain and are separately driven at equal speeds by the belt pulley at the left-hand end of the machine. The material at this point is rolled rather than ground. As before, the rolls are fitted with scrapers. The feed hopper is provided with an adjustable shutter and a power-driven feed roll which ensures the material being delivered evenly along the length of the rolls, an important item in successful working. These rolls are made in various sizes to treat from 12 to 20 cwt. of material per hour, and in their driving consume from 8 to 10 b.h.p.

The final reduction of the material to meal of the proper degree of fineness is carried out in powerful rolls, of which an example made by Messrs. Manlove, Alliott is illustrated in Fig. 7. The action required is one of rolling not of grinding. The five rolls in the machine illustrated are stacked vertically, and are driven positively by means of a double helical gear-wheel at each end of each roll. The rolls rotate at equal speeds and are either plain or lightly fluted, both styles being often found in the same machine at once. The material leaving the hopper at the top is guided in a sinuous course through the rolls by means of four inclined plates let into the machine framework on alternate sides of the rolls. The lowest roll spindle carries two fast and

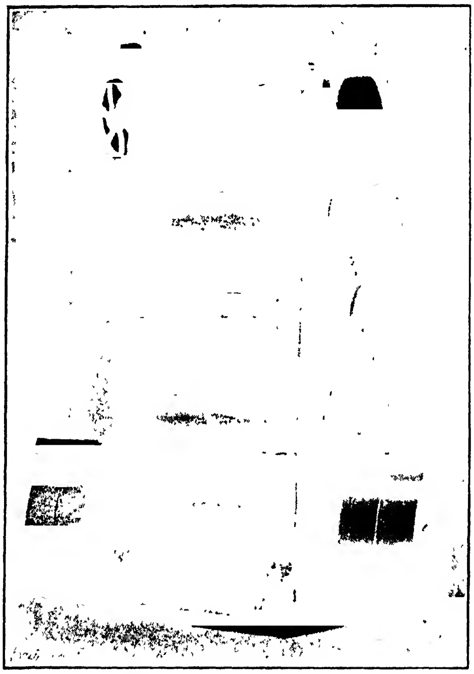


FIG. 7.—Final Reduction Rolls—Manlove, Alliott.

two loose pulleys. A simple belt shifter is provided which permits of the two belts being moved simultaneously. This avoids the risk otherwise present of causing damage by transmitting the drive entirely through the gearing at one end of the rolls. The output of these rolls varies from 10 to 20 cwt. per hour.

PREPARATORY TREATMENT OF LINSEED, ETC.

Linseed, rape seed, and similar small seeds require very little special preparation for pressing. Beyond screening to remove foreign matter such seeds have only to be crushed between rolls to convert them to meal suitable for pressing.

An appliance for screening linseed and similar seeds, made by Rose, Downs & Thompson, Ltd., of Hull, is illustrated in Fig. 8. This machine consists of a cast-iron casing containing a slowly rotating cylindrical screen into the interior of which the seed is delivered. Inside the screen is a fast-moving paddle which throws the seed against the interior surface of the screen. The seed is delivered to the machine at the

orifice A, and is carried into the screen by the action of a short worm fixed on the end of the paddle shaft. The screening surface is formed of perforated sheet steel and covers the screen framework from the line BB to the line CC. The screened seed falling through the perforations collects within the vee-sectioned hopper formed by the lower walls of the main casing and is carried by a rotating worm either to the outlet D or the outlet E, according to the formation given to the worm. The tailings fail to pass through the perforations of the screen and are delivered through the gap left beyond the line CC to an orifice F, divided from the orifice E by a partition. The machine is driven from the right-hand end of the paddle shaft. The discharging

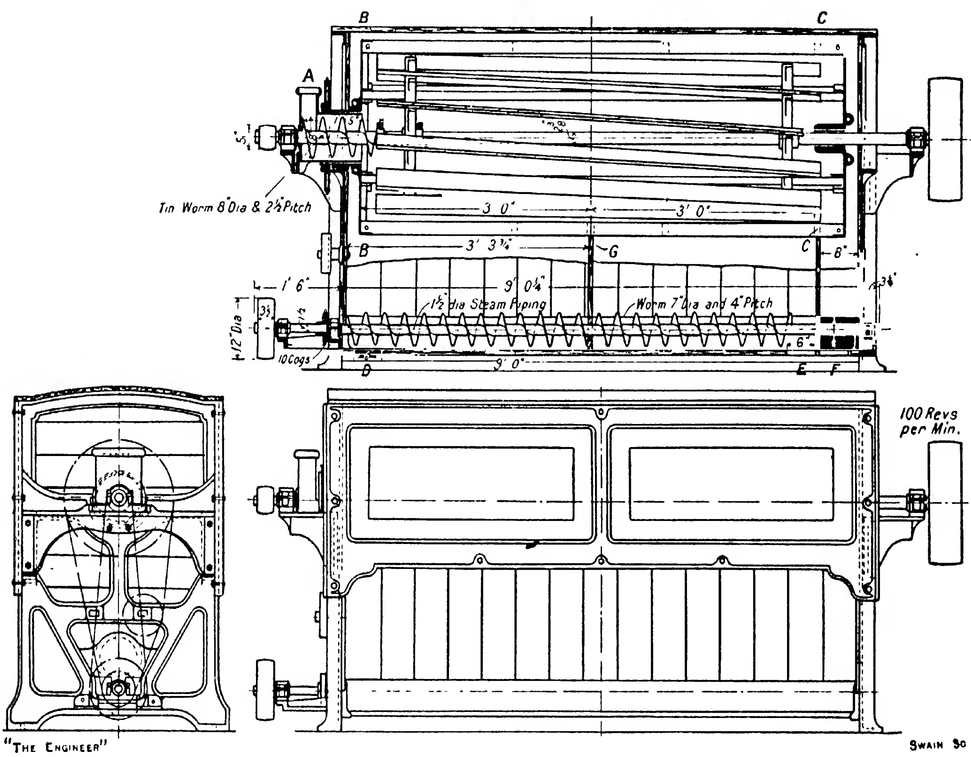


FIG. 8.—Screening Machine for Linseed, etc.—Rose, Downs & Thompson.

worm is driven by belt from the left-hand end of the paddle shaft and itself drives the cylindrical screen by chain and sprocket wheels. The machine illustrated has an output of 28 to 30 cwt. per hour and requires about 3 b.h.p. to drive it. The paddle shaft runs at 100 revolutions per minute, the screen at 12, and the discharging worm at about 42.

On occasion a screen of this type is required to deal with seeds or other such material of varying size, and to separate a batch into two portions besides the tailings. For instance, the left-hand half of the screened surface may be perforated $\frac{5}{32}$ in. mesh, and the right-hand portion $\frac{5}{8}$ in. The hopper is then divided by a partition such as at G, and the discharging worm is made in two corresponding portions, one right, the other left-handed. In this way the finer-sized seeds are delivered through the orifice D, the coarser at E, and the tailings at F.

A set of rolls suitable for crushing linseed, etc., made by Manlove, Alliott & Co., Ltd., of Nottingham, is illustrated in Fig. 9. The rolls are five in number, measure 16 in. in diameter by 42 in. long, are stacked vertically and are quite plain on the surface. As usual, they are ground with great truth and are forced on to their shafts by hydraulic pressure, being thereafter keyed at both ends. The lowest roll is driven at both ends and is provided with two additional pulleys, from which belts are taken to similar sized pulleys at each end of the third and fifth rolls. The bearings for all the rolls except the lowest are free to slide vertically in their housings. Consequently

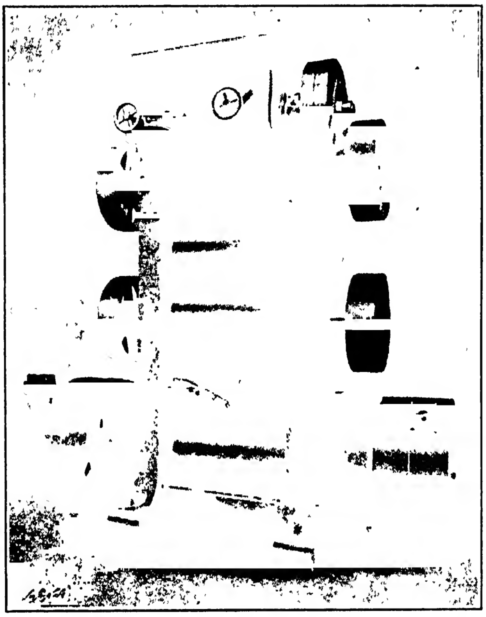


Fig. 9.—Rolls for Linseed, etc.—Manlove, Alliott.

the pressure exerted on the seed being reduced increases with each step in its descent from the hopper. The second and fourth rolls are driven simply by the friction between them and their neighbours. The consequent slip of these rolls is relied upon to give the grinding action which, to a small extent, should accompany the crushing action of the machine. Means are provided whereby the two upper rolls may be held slightly raised so as to increase the feed. Additional means are also provided whereby, if desired, the dead weight of the rolls may be assisted by the action of tightening screws and springs. The capacity of the rolls illustrated is about 15 cwt. of seed per hour.

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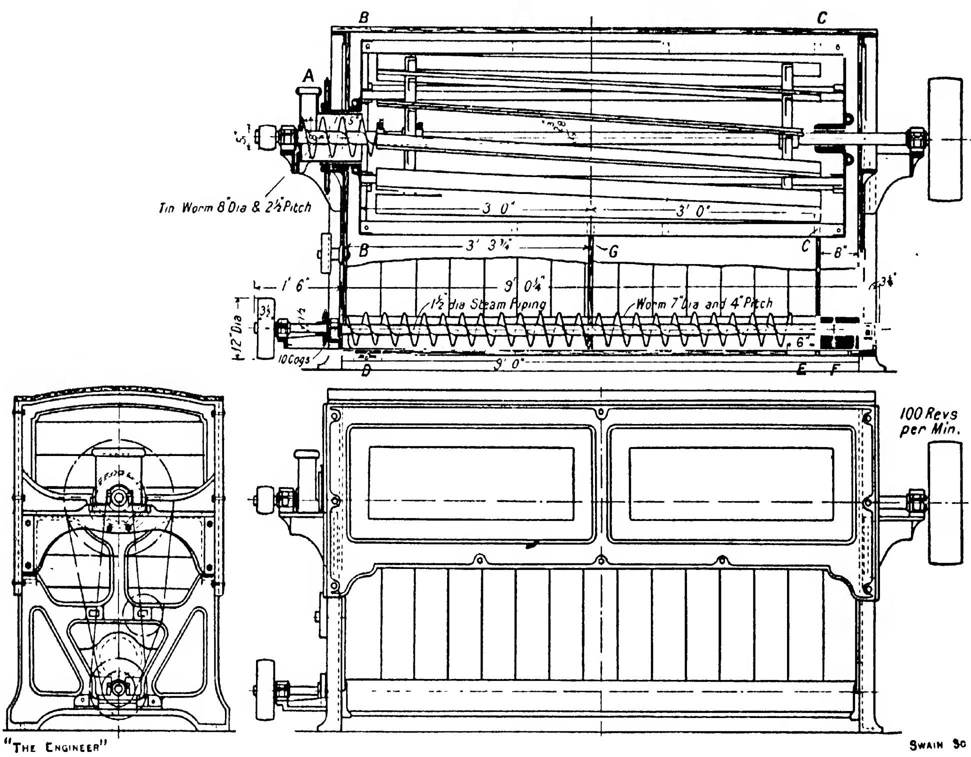

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and the nut kernels. The sample of fruit from which the original photograph reproduced in this engraving was prepared was kindly supplied to us by A. F. Craig & Co., Ltd., Caledonia Engine Works, Paisley. We were fortunate in securing this sample, as the fruit rapidly deteriorates after being gathered, and is therefore rarely seen in this country. A bunch of palm fruit as taken down from the tree is shown in Fig. 11, for the original of which we are indebted to Messrs. Manlove, Alliott. Such a bunch may weigh round about 14½ lb. and measure about 12 in. long by 10 in. across. From the pericarp B (Fig. 10) palm oil is obtained, while from the kernels E a totally different oil, palm kernel oil, is recovered. Owing to the rapid deterioration which the pericarp suffers after the fruit is gathered, it is impracticable to ship the whole fruit to Europe for treatment. In general, therefore, the practice is to recover the palm oil from the pericarp at or near the plantations in Africa, and to send the nuts or kernels overseas for treatment at home.

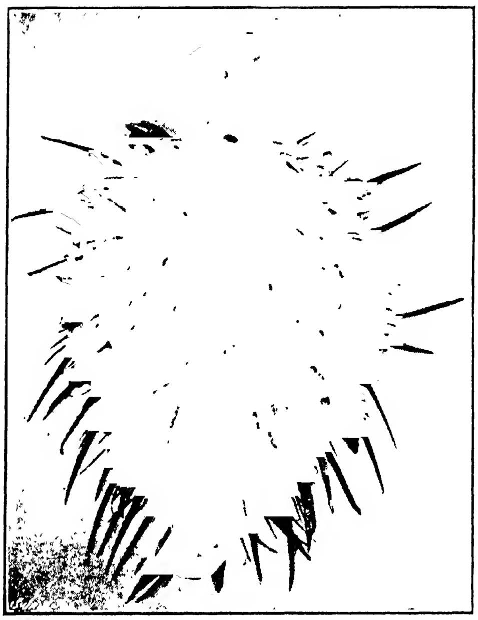


Fig. 11.—Bunch of Palm Fruit.

Treatment of the Palm Fruit.

Until recently, and still to a considerable extent, the production of palm oil was in the hands of the natives. The method they use is crude. Not only do they lose, by following it, from a half to two-thirds of the possible oil yield, but the oil obtained is apt to have developed in it elements which lower its commercial value. The fruit when ripe, is deliberately allowed to ferment in the presence of water, so that the hard pericarp may be softened and readily separated from the nut. The separation is effected simply by beating the softened fruit to a pulp, and thereafter picking out the nuts from the mass by hand. The pulp is then boiled in water, and the oil, rising to the top, is skimmed off. This method of working induces hydrolysis in the oil—that is to say, the oil combines with water, and is changed from a neutral condition to an acid one by the breaking down of its constitution into free glycerine and free fatty acid. Once hydrolysis is started it is liable to continue so that frequently palm oil is received at its European destination containing as much as 50 per cent. of free fatty acids. The commercial value of the oil is proportionately reduced.

Many attempts have been made to treat the fruit in a scientific manner, the direct objects being to obtain the full yield of oil from the pericarp, and to do so without causing the oil to decompose, or, to use the technical term, to hydrolyse. It is obvious that to prevent hydrolysis the fruit must be subjected to a treatment which in no way calls for its being placed in contact with water in any form. This, the ideal process, is commonly spoken of as the "dry" method. Certain "dry" methods, notably a German one, have been proposed, and have received some application which have not come up to the ideal standard, for at some stage or other water or steam has been used to assist the recovery of the oil or the separation of the pericarp from the nut.

Separation of the Pericarp.

The chief difficulty undoubtedly lies in the effective separation of the pericarp without waiting for it to soften, either by natural deterioration or by fermentation in presence of water. What may be called a compromise process may first be described. The machinery for this process has been supplied by Manlove, Alliott & Co., Ltd., of Nottingham, and we are informed that good, if not ideally satisfactory results have been obtained with it. Under this method of working the fruit freshly gathered is taken to a machine provided with a revolving shaft, on which are mounted several bayonet-like knives. Here the fruit with its nuts is cut and churned up into a pulp.

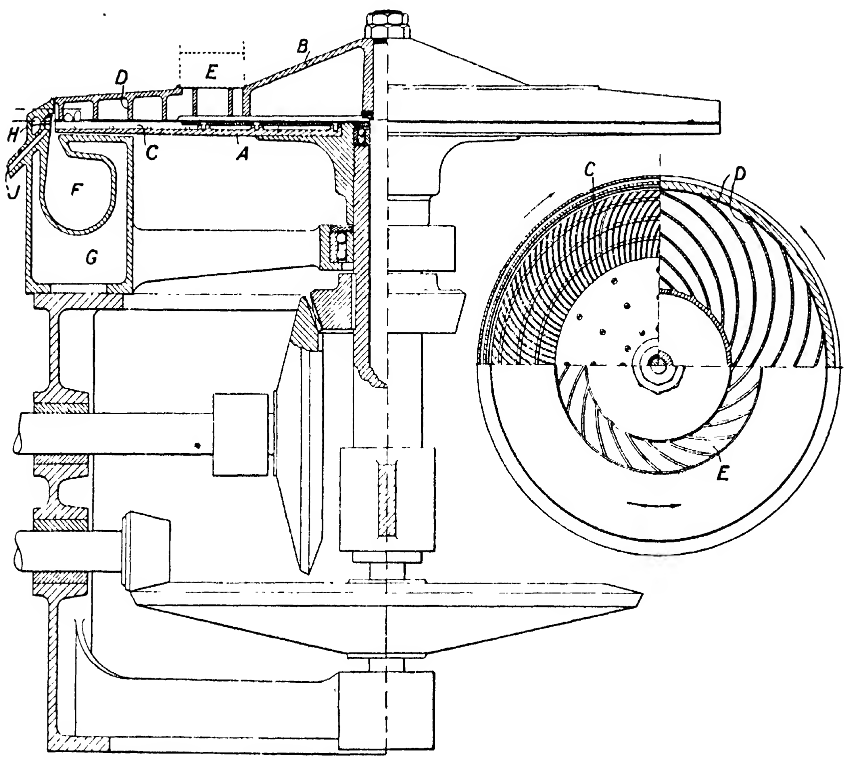


Fig. 12.—Fairfax's Depericarping Machine.

The mass, sufficiently reduced, is then placed in a cage press, and pressure applied to it until the nuts are heard to begin to crack. The oil which flows away is, of course, of good quality, but in quantity does not represent the full oil content of the pericarp. The half-pressed material is therefore boiled up with water to recover the remaining oil, and to complete the separation of the pericarp from the nuts. The oil skimmed off the boiling water is naturally of an inferior quality to that running from the press.

Palm oil is a very valuable substance, and would be still more so were it possible to obtain it in good condition in large and regular supplies. Consequently we find that much attention has been, and is being, devoted to the design of a satisfactory depericarping machine for palm fruit which will permit the whole pericarp to be treated by a truly dry process. To Messrs. A. F. Craig, of Paisley, we are indebted for the

particulars and illustrations which we are enabled to give of their "Caledonia" dry process, and of the machines designed to give it effect.

The depericarping machine used under this process is the patented invention of Mr. H. G. Fairfax, and is illustrated in Fig. 12. In Fig. 13 we give a working drawing of the same invention, as carried out on practical lines by Messrs. Craig. The machine consists essentially of two parts, namely a rotating table A (Fig. 12), and a rotating cover B, the former running quickly in one direction and the latter slowly in the opposite direction. The table carries a series of closely spaced curved blades or abraders C. The cover is formed with a series of wider spaced oppositely curved ribs D. The fruit is fed into the cover through the annulus E, and passing outwards is stripped of its pericarp by the blades C. The counter curvature cf the blades C and the ribs D has, of course, an important influence on the stripping action. The loosened pericarp falls between the blades C and is at once ejected outwards by cen-

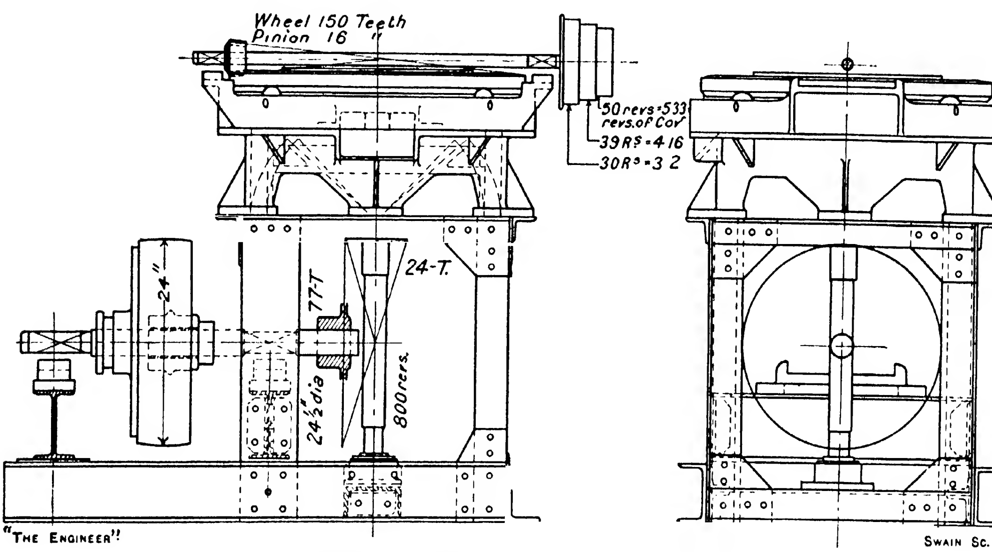
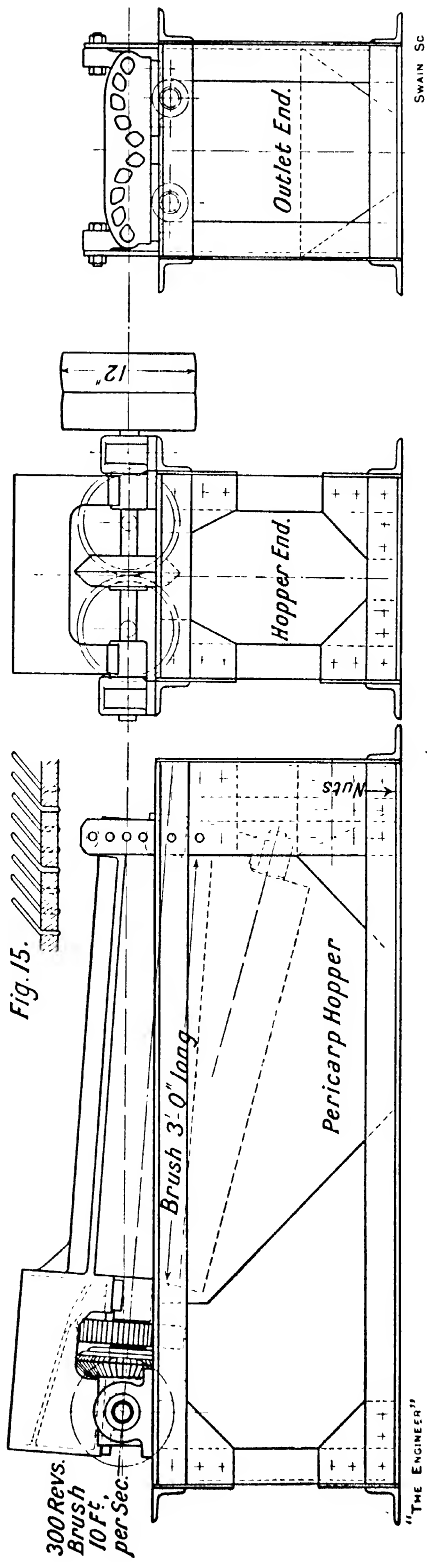


FIG. 13.—Depericarping Machine for Palm Fruit—A. F. Craig.

trifugal force over the edge of the table. Here it falls into the receptacle F, which, to facilitate the movement of the pericarp, is steam heated. It will be noticed that the steam jacket G also extends beneath more than half the effective part of the blades C. The nuts are too large to pass between the blades on the table. Instead they are shot out through holes round the upstanding lip of the machine casing, and are thus collected separately from the pericarp. Any oil which may be set free during the stripping of the pericarp is shot against a screen H and flows away down the outlet J.

The nuts as they leave the depericarping machine may have small portions of the pericarp still adhering within the irregularities of their shells. To recover such portions the nuts may be passed through the patented brush machine illustrated in Fig. 14. This, like the depericarping machine above described, is made by Messrs. Craig, of Paisley. It consists, in essence, of two cylindrical brushes, 3 ft. long and about 7⅝ in. in diameter, revolving side by side at 300 revolutions per minute, beneath a casing or cover embracing the upper portions of the brushes. The brush spindles rotate in bearings fixed to the casing, and are driven through bevel gearing from a shaft journalled cross-wise on the main frame of the machine. The casing is also journalled

to this cross shaft, so that it and, with it, the brushes may be set longitudinally to any desired inclination. It is fixed in position at the other end by means of bolts passed through one or other of a series of holes formed in a projection on the main frame. At the driving end of the machine the casing is provided with a hopper, into which the nuts are fed. From this the nuts enter one or other of ten grooves formed on the underside of the casing. The inclination of the casing causes the nuts to travel down these grooves to the outlet end, and in so doing they are turned and brushed all over by the brush bristles, which form, as it were, the fourth side of the grooves. The pericarp fragments removed by the brushes fall into a hopper between the main frame uprights. The cleaned nuts emerging from the ends of the grooves are caught in a separate hopper. The machine is designed nominally to deal with about 12 cwt. of nuts—say, 134,000 nuts—per hour.* The ten grooves hold at any one time 400 nuts. The nuts are in contact with the brushes for about 11 seconds each. By altering the inclination of the brushes and casing the output can be adjusted within certain limits. The two brushes revolve in opposite directions, and are covered with "wire cloth" formed of leather, in which are fixed projecting wires as indicated in the sketch, Fig. 15.



FIGS. 14 AND 15.—Palm Nut Brushing Machine—Craig.

TREATMENT OF THE NUTS.

The pericarp thus recovered is pressed at once. The nuts as cleaned by the brushing machine are dried either naturally or artificially to loosen the kernel within the shell. They have then to be cracked open and the kernel separated from the shell fragments. A cracking and separating machine, made by Messrs. Craig, of Paisley, is illustrated in Fig. 16. The hopper of this machine is vee-shaped in section, and is provided internally with an inverted vee-shaped surface, which divides the nuts into

* These figures imply that the nuts run at about 11,000 to the hundredweight. They vary in size and sometimes number as few as 5,500 to the hundredweight.

two streams. Each such stream passes down a pipe A cast on the outside of a semi-cylindrical casing, which contains a drum driven at a high speed, about 1,000 revolutions per minute. The nuts fall into the interior of the drums and are shot out by centrifugal force through slots in the drum periphery. Striking forcibly against the inner wall of the surrounding casings, the shells are cracked open, and with the kernels fall to the foot of the casings, whence they are conducted on to the shaking separator, disposed between the legs of the machine frame. The separator consists of an inclined

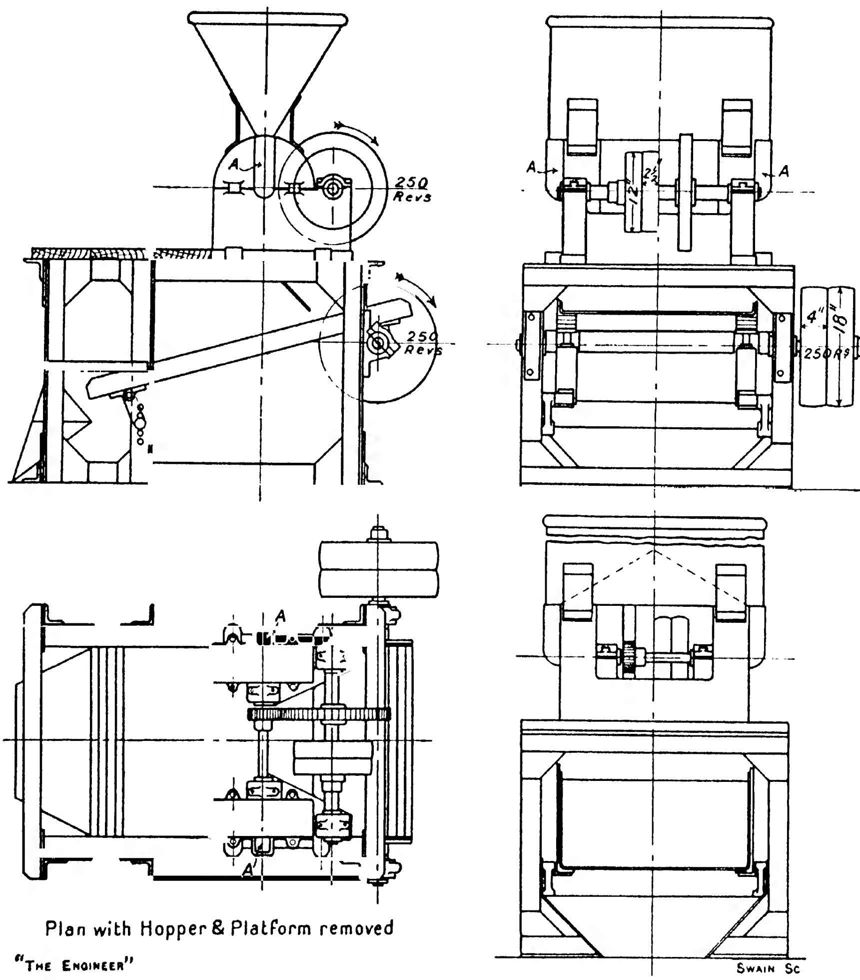


FIG. 16.—Palm Nut-cracking and Separating Machine—Craig.

tray, the bottom of which is formed with a special surface. At the lower end it is overhung on swinging links, the pivot points of which can be varied to give the tray the required inclination. At the higher end it is journalled to a short-throw crankshaft driven at 250 revolutions per minute. The bottom of the tray is not perforated. The shaking action, combined with the special construction of the bottom surface, results in the kernels being passed to one end of the tray while the shell fragments pass to the other. Falling over the ends they are collected in hoppers. The shells can be used as fuel, either under a boiler or in a gas producer.

In general the kernels are shipped to oil mills in Europe or elsewhere. Their preliminary treatment closely agrees with that accorded to copra, much the same shredding and reducing rolls being used to convert them to the form of meal. Certain considerations, however, have led the factories in Africa to contemplate undertaking the work of recovering palm kernel oil within their own walls. The chief of these is the fact that palm fruit is not available all the year round, so that during the "off" season, if palm oil alone is dealt with, the expensive presses and other plant must lie idle. By a little additional capital expenditure the factory can be readily fitted for

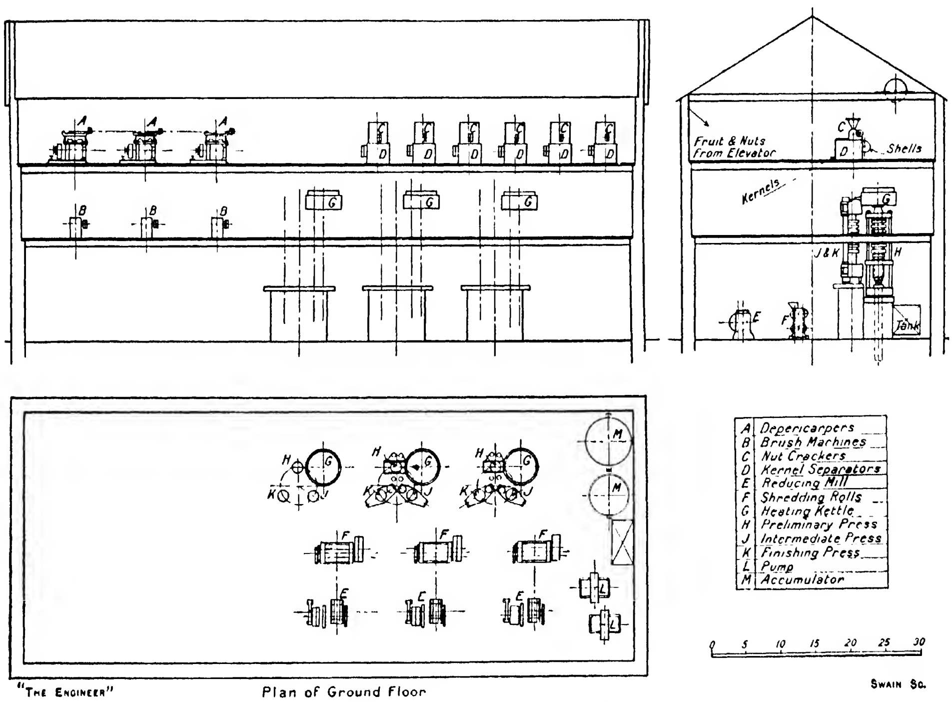


Fig. 17.—Palm and Palm Kernel Oil Mill—Craig.

treating the kernels, so making it possible to fill in the otherwise idle period, and to keep the staff together.

A Palm and Palm Kernel Oil Factory.

In Fig. 17 we give the general lay-out of an African mill working on Messrs. Craig's "Caledonia" dry system. The equipment of this mill includes preliminary screens for removing any sand or other material which the natives may be tempted to mix with the fruit, three depericarping machines, three brush machines, six combined nut-cracking and kernel-separating machines, three reducing mills, three sets of shredding rolls, three heating kettles, and three crushing presses. The latter are of the bar cage type, to be described in a later chapter, and have each three sections, namely, a preliminary, an intermediate, and a finishing press. Equipment is also provided for sealing up the palm oil in tins as soon as it has been expressed from the pericarp. The design of this factory is such as to enable it to deal with about 50 tons of fresh fruit daily or with the kernels derived from about 100 tons of nuts.

As showing the importance of oil palm fruit, we may remark that in 1913 the United Kingdom imported palm oil to the value of £2,326,842. In the same year Germany imported palm kernels to the value of £3,314,278, while other countries, including our own, took together kernels valued at £1,918,974. The outbreak of war greatly affected matters. In 1914 our imports of palm kernels were valued at £1,411,928, and in 1915 at about £2,500,000. Even so the palm fruit industry may yet be said merely to be in its infancy.

CHAPTER V

PREPARATORY MACHINERY FOR COTTON SEED AND CASTOR SEED

Cotton seed, as we remarked in our second chapter, is, so far as the oil milling industry is concerned, of two varieties, one being the black Egyptian seed, the husk of which as received is practically free from adhering cotton fibre, and the other the white American or Indian seed, to which quite a considerable quantity of cotton fibre may be adherent. The "white" seed is white merely by virtue of the adhering lint. In Fig. 18 we reproduce a photograph of some samples of the two varieties of cotton

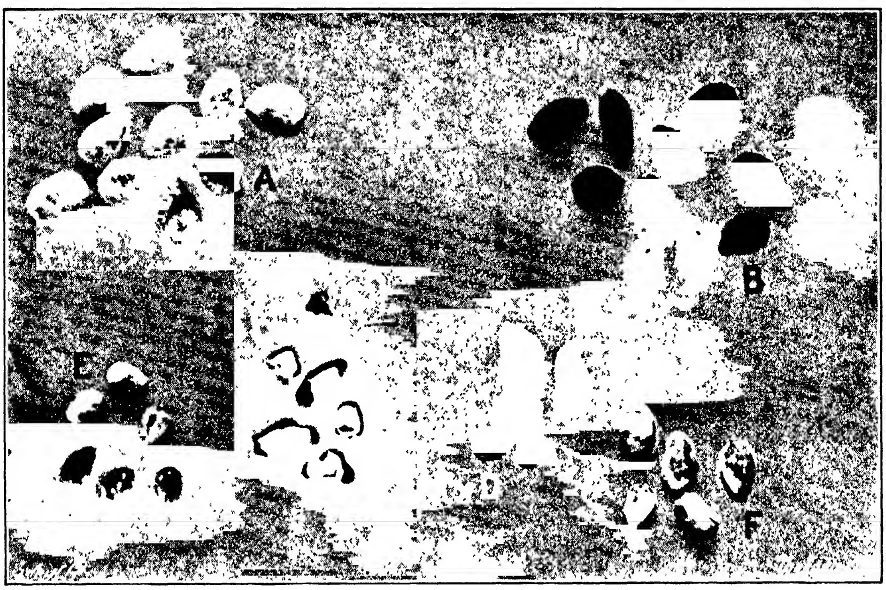


Fig. 18.—American and Egyptian Cotton Seed.

seed, kindly supplied to us by Rose, Downs & Thompson, Ltd. At A the American seed is shown, and at B the Egyptian. The husks C and D respectively are hard and tough, the American being, if anything, harder and tougher than the Egyptian. The oil-bearing kernels E, F, are soft yellow or whitish bodies which can readily be crushed between the fingers. The American kernels are distinctly smaller than the Egyptian. The engraving is facsimile as to the size of the seeds.

In this country it is a common custom in the production of cotton seed oil simply to reduce the seed as received between rolls and then to press the resultant meal in the usual way. In this way the husks and, in the case of the American seed, the adhering cotton lint pass into the cake. There does not appear to be any serious agricultural objection to this course, for cotton seed cake is in great favour as a cattle food. An excessive amount of lint in the case of the American seed, such as is sometimes found on seed that has been badly ginned, would, undoubtedly, lower the value

of the resultant cake. Moreover, the excess lint has a distinct commercial value as cotton. Hence, for two reasons it may well pay the oil mills handling American cotton seed to re-gin or de-lint it as a preliminary to treating it in the rolls and presses.

De-linting.

A cotton seed de-linting machine as employed at an oil mill is almost indentical with a cotton gin as employed by the cotton grower. In Fig. 19 we give a drawing the original of which was supplied to us by Rose, Downs & Thompson, Ltd., showing the general arrangement of a cotton seed de-linter. The seed delivered to the machine at A is admitted by a power-driven feed roller in an even stream into the seed box B. One wall of this box consists of a grating C through which project the tips of a large number of fine-toothed circular saws. These saws number usually 106, and are spaced apart on the shaft D by means of thin cast-iron distance washers. The saw cylinder runs at 375 revolutions per minute. The seed in the seed box is churned up by the saws, the teeth of which catch on the lint and remove it in great part from the seeds. The de-linted seed escapes from the shoot E under the control of a hinged regulating board, not shown in the drawing. The lint adhering to the saws is picked off the teeth by a circular brush mounted on the shaft F and revolving at about 1,360 revolutions per minute. From this brush the lint is deflected into a flue G by means of an air draught produced by a fan on the shaft H. The draught is regulated by the damper J and the handle K. From the flue the lint is delivered into a "condenser" L, a casing containing a revolving cylindrical cage of wire cloth, on which the lint collects as a roll and from which it is removed from time to time. This machine absorbs from 4 to 8 b.h.p., and can treat from 3 to 20 tons of seed per twenty-four hours, according to the nature of the seed and the extent to which it is desired to de-lint it. On the average it may be expected that round about 20 lb. of lint will be obtained from a ton of seed. The presence of iron particles amongst the seed fed to the machine has to be guarded against, because of the very destructive effect such material would have on the saw teeth. It is, therefore, a common

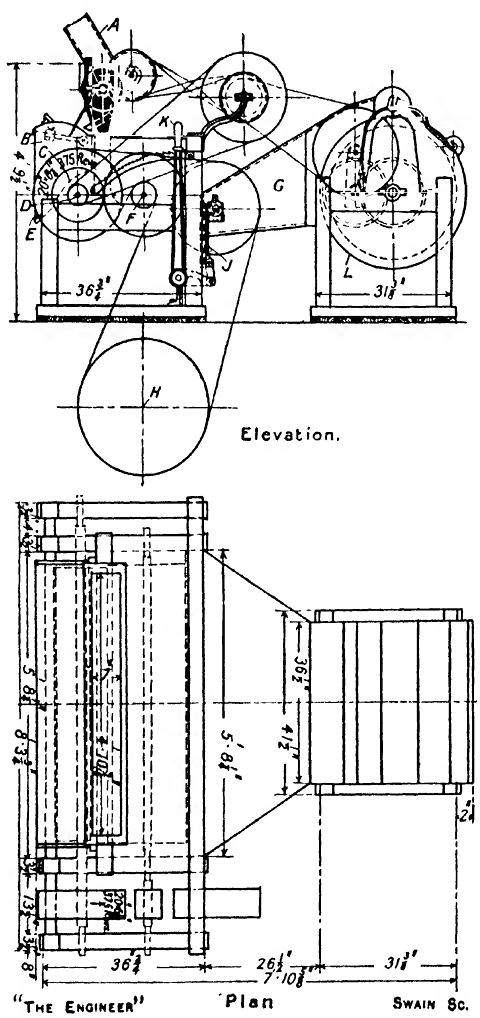
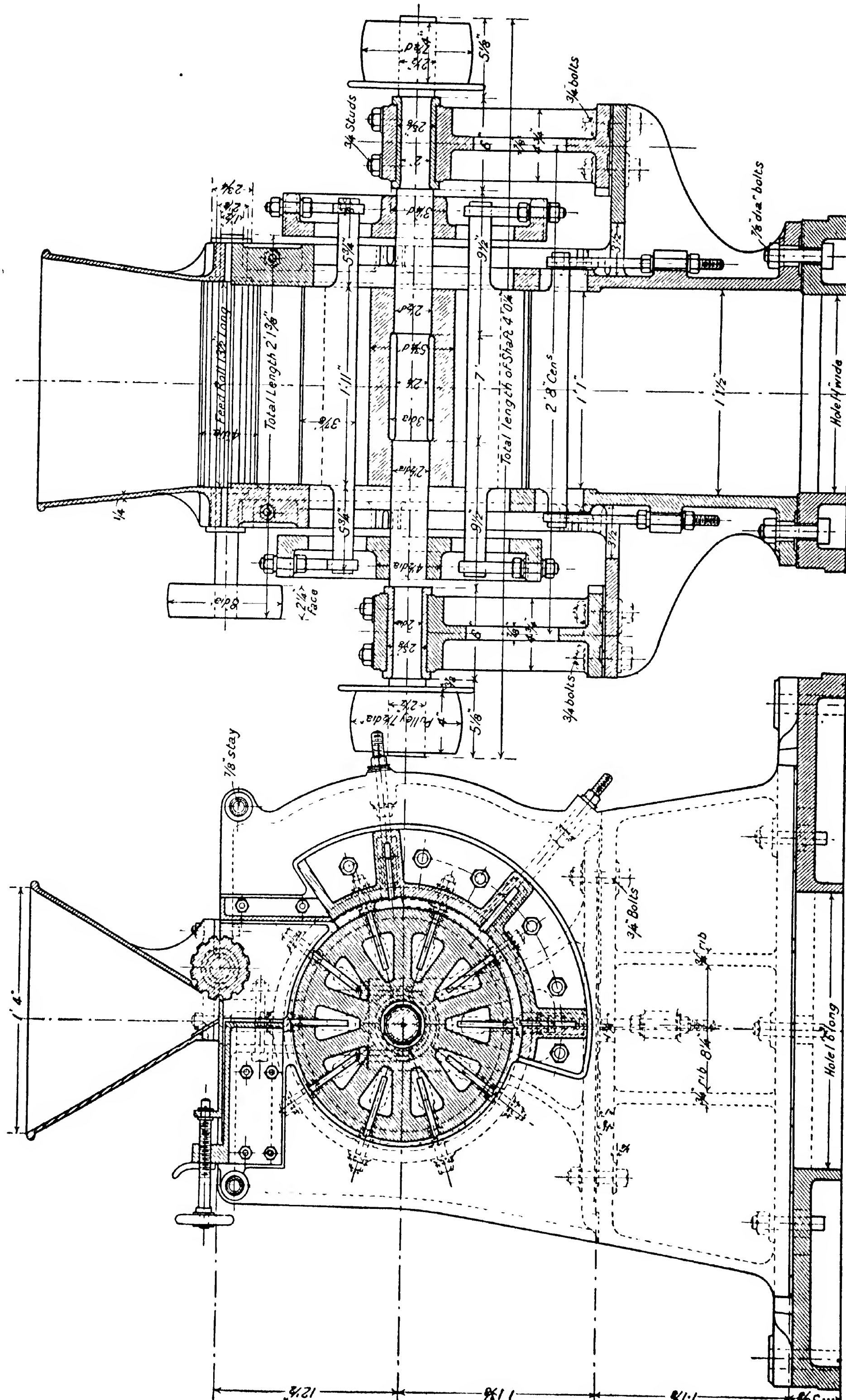


Fig. 19.—Cotton Seed De-linter—Rose, Downs.



"The Engineer"

Swain Sc.

Fig. 20.—Cotton Seed Decorticating Machine—Rose, Downs & Thompson.

practice to embody in the seed box a series of electro-magnets over which the seed is compelled to pass before it reaches the saws.

Decorticating Cotton Seed.

Following American practice, it is becoming common in this country, in some cases, to remove the husks or cortex of the seeds before crushing and pressing them. In this way the kernels, or "meats" as they are called, alone are pressed. The advantages of this practice lie in the freedom from discoloration of the oil, otherwise liable to be produced by the colouring matter in the husks, the improved quality of the cake, and the increased output of oil obtained from a press of given size.

A decorticating machine for cotton seed, made by Rose, Downs & Thompson, Ltd., is shown in sectional elevation in Fig. 20. The machine may be described as

Fig. 21.—Castor Seed—Pods, Beans and Kernels.

consisting of a rotating barrel carrying ten knives crosswise on its periphery, and of a fixed "breast" carrying three stationary knives similarly disposed crosswise. The seed is fed on to the barrel from an overhead hopper by means of a power-driven fluted feed roll, working in conjunction with a hand-regulated shutter across the hopper mouth. The "breast" is made in four sections, the divisions being coincident with the planes of the central lines of the three "breast" knives. The seed falling on to the rotating barrel is caught between the rotating and fixed knives. The husks and kernels together are carried round to the lower edge of the "breast" and are there collected. This machine is made in several sizes. That size illustrated has an output of about 10 cwt. per hour, and to drive it absorbs some 6 b.h.p. The knife barrel in this case runs at 1,500 revolutions per minute.

Considerable mechanical interest attaches to the method adopted by the designers of this machine for carrying the barrel blades. Three conditions have to be met. First, the knives have to be readily adjustable radially to suit possible variations in the size of seed delivered to the machine for treatment. Secondly, the knives have to be easily removable, so that they may be taken out and sharpened. Thirdly, the

knives must be fastened in some particularly secure manner, to withstand the centrifugal force on them arising from their high speed of rotation. To fulfil these requirements, no attempt, it will be seen, is made to fix the knives directly to the barrel itself. The barrel is simply slotted to allow the knives to pass through it. In each side frame of the machine a circular central hole is formed. Through these holes the ends of the knives project. Beyond each frame a flanged and slotted disc is fixed to the barrel

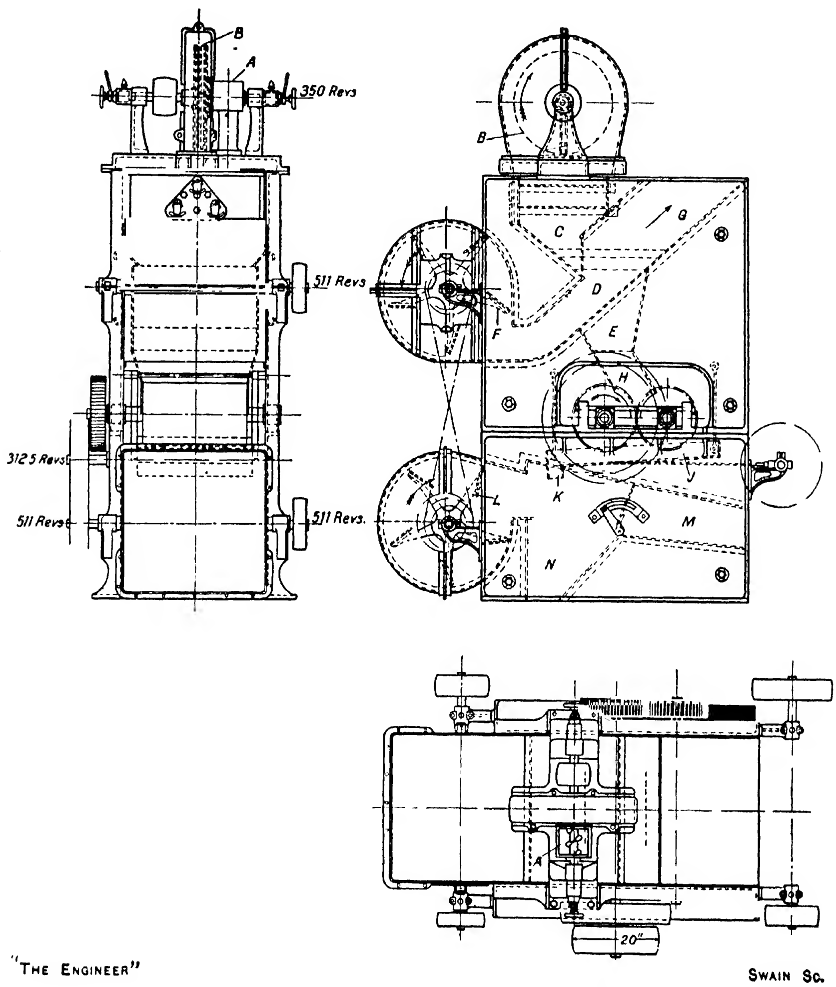


FIG. 22.—Castor Seed Sheller—Rose, Downs & Thompson.

shaft. The ends of the knives are carried through the slots in these discs and are gripped in the slotted heads of bolts radiating inwards from the disc flanges. In use, the flanged discs are enclosed within a stationary sheet metal casing to prevent accidents. A similar method is adopted for securing the " breast " knives in place. In this case the slot-headed bolts are attached to bosses projecting from the main framing.

The further treatment of cotton seed requires no special remark. It is crushed, preparatory to pressing, in rolls closely similar to or identical with those used for linseed or even copra, see Figs. 4, 5 and 9, Chapter III.

practice to embody in the seed box a series of electro-magnets over which the seed is compelled to pass before it reaches the saws.

Decorticating Cotton Seed.

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Castor Seed.

The distinguishing feature of castor seed as an oil-bearing substance lies in the fact that the portion which carries the oil is enclosed within two outer casings. Fig. 21, prepared from samples kindly supplied by Rose, Downs & Thompson, Ltd., shows the seed and its component parts. At A the seed as grown is illustrated. The pod, it will be gathered, is in three sections, B. The removal of the husk C from either of these sections reveals a deep-coloured prettily-marked bean D. The cortex or

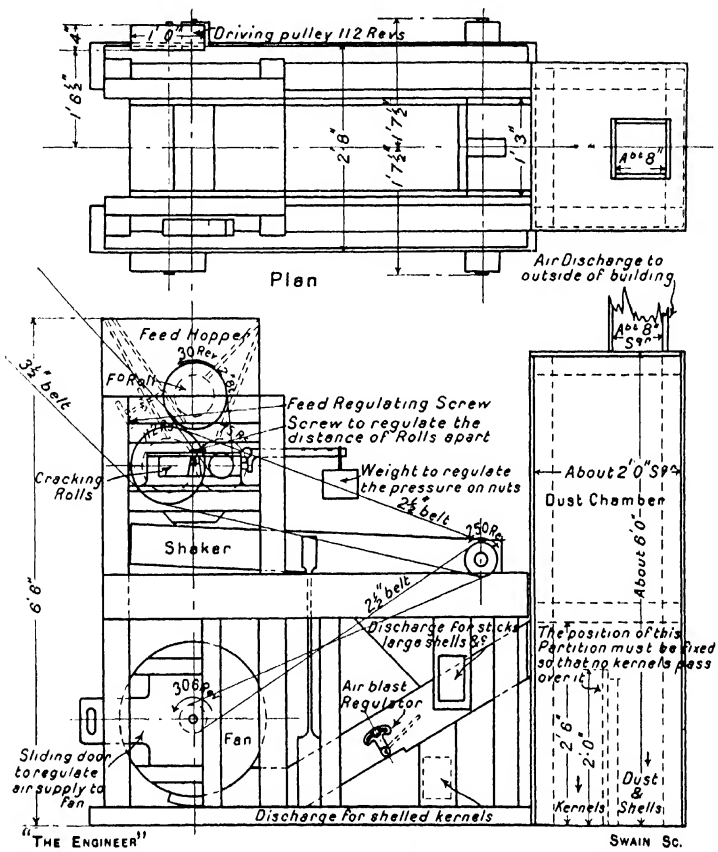


Fig. 24.—Castor Seed Decorticator & Separator—Robert Middleton.

shell E of these beans is thin and brittle, and encloses the white oil-bearing kernel F. The engraving is facsimile as to size.

Shelling.

The first step in the preparation of the seed for pressing is the removal of the outer shell or pod. A machine for this purpose, a castor seed sheller, made by Rose, Downs & Thompson, Ltd., is represented in Fig. 22. The seeds are fed into a small hopper A at the top of the machine, and are thence carried by a rotating worm between a pair of discs B. The distance between these discs can be regulated by the means indicated to suit requirements. The pods, rubbed between the discs, have their outer casings broken, and escaping, fall through a special distribution device into the hopper

C, and thence past a hinged regulating flap, across the channel D into another hopper E. While the stream is crossing the channel D it meets a blast of air from the fan F. The force of the blast is regulated so that the lighter material only, the fragments of the outer husk, may be carried away, as at G, into a suitable collecting chamber. The heavier portions, the beans with what husk may yet adhere to them, pass from the

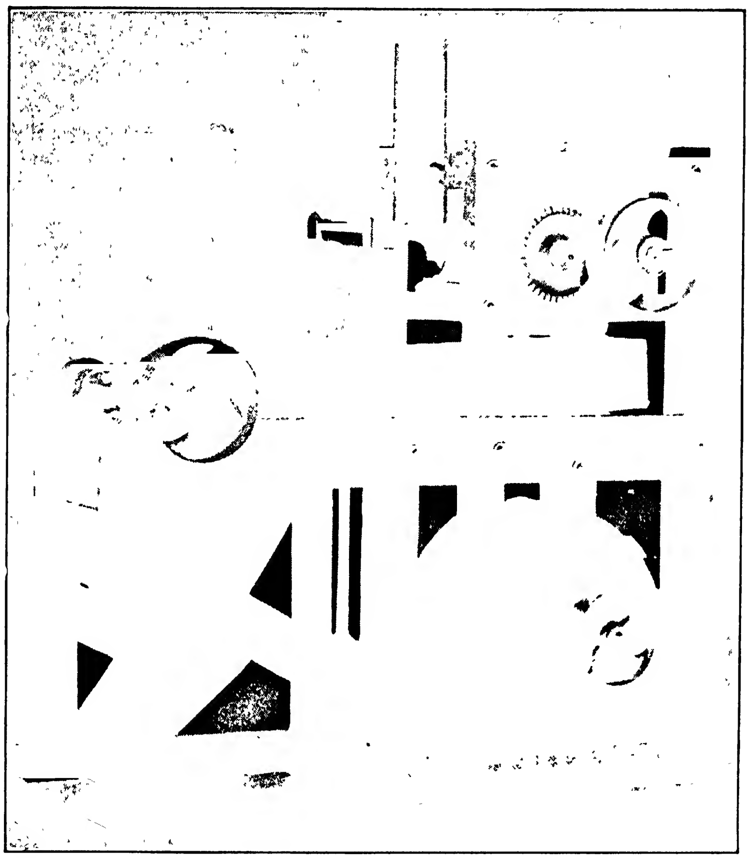


FIG. 25.—Castor Seed Decorticator and Separator—Robert Middleton.

hopper E to a pair of rolls H, the distance apart of which is carefully adjusted to suit requirements. Leaving these rolls, the beans and husk fragments fall on to a shaking separator J. Leaving this at K, the material in descending meets a blast of air from a second fan L. This blast carries away with it down the passage M the lighter fragments of the outer pod yet remaining in the stream, but is not sufficiently strong to prevent the beans from descending into the hopper N. The speeds of the various parts of this machine are marked on the drawing. The example illustrated has an output of 10 to 20 cwt. per hour, and absorbs 6 to 8 b.h.p.

Decorticating Castor Seed.

The machine just described removes the outer husk of the seed. Doubtless it may remove some of the inner shell as well, but for this purpose it is usual to pass the

seed through a special decorticating machine after it has gone through the sheller. A combined decorticator and separator for castor seed, made by Rose, Downs & Thompson, is illustrated in Fig. 23. In this the beans are distributed from a hopper, provided with a fluted feed roll and a hand-regulated shutter plate. The beans fall and are cracked between a pair of cylindrical rolls, the space between which can be suitably regulated by hand. Leaving the rolls, the broken shells and kernels fall on to a shaking separator. This separator consists of two series of contra-sloping trays, extending between and united to a pair of vertical side frames. The frames referred to are hung by means of eight flat steel springs from the main framing of the machine, four of the springs being within the main frames, and four, at a lower level, being external to them. The separator is vibrated by means of a pair of flexible connecting rods lying outside the main frames, and coupled up to a short-throw crank-shaft extending across the main frames at the right-hand end, as seen in the elevations in the engraving. An air trunk with a fan at its foot is arranged between the main frames at the crankshaft end. This trunk has four separate orifices, the blasts from which can be controlled independently by shutters operated by racks and hand-wheels. The shells and kernels falling from the rolls travel under the shaking action from one tray to the next in the series. The kernels complete the whole course, and fall off the separator at the right-hand end of the lowest tray. The lighter portions of the beans, the shell fragments, under the action of the air blast, fail to complete the whole course, and are carried off over the left-hand end of one or other of the trays into a vertical passage, from the foot of which they are eventually discharged. Doors are provided in the outer wall of this passage to regulate the egress of the air blast.

The output of the size of machine illustrated is 20 cwt. of beans per hour. Seven brake horse-power is absorbed in driving it. The crushing rolls run at 100 revolutions per minute, the separator shaker shaft at 500, the feed roll at 120, and the fan at 1,000.

It may be remarked that the practice of freeing the castor seed kernel from its inner or second covering is not by any means universal. It is more or less necessary, if a good, clear quality of hot-drawn oil is desired, but for many purposes the oil obtained by pressing the beans with only the outer pod removed is found sufficiently good to justify the practice.

Another castor seed decorticator—made by Robert Middleton & Co., of Sheepscar Foundry, Leeds—is shown in Figs. 24 and 25. The design is considerably different from that illustrated in Fig. 23, but the principle of action is much the same. The hopper from which the seed passes to the cracking rolls is provided with the usual screw-adjusted flap and power-driven feed roll. The cracking rolls are 8 in. in diameter, are of cast iron, turned and fluted, and are driven at differential speeds. They are journalled in horizontally sliding bearings, the distance between the rolls being regulated by means of a pair of wedge-headed bolts. A pair of weighted bell-crank levers serve to regulate the pressure exerted by the rolls on the seed in the manner indicated in Fig. 24. From the cracking rolls the kernels and husks fall on to a shaking separator carried on spring rods, and vibrated by a short-throw crankshaft running at 250 revolutions per minute. On the shaker the charge is tossed about, and those portions of the cracked shells which may yet be adhering to their kernels are separated therefrom. Towards the lower end of the shaker the charge passes on to a perforated portion of the bottom. Through this the shells, kernels, and dust pass. Sticks, portions of the outer husks and other large-sized extraneous matter pass across it, and are discharged through an opening in the bottom into a shoot. The shells, kernels, and dust leaving the shaker fall into a trunk, up which a blast of air is blown from a fan at the foot. The kernels, or the majority of them, succeed in passing across this trunk, and fall into

an outlet shoot. The lighter portions are carried by the air blast into a dust chamber. At the foot of this chamber is a partition 2 ft. high, the position of which is adjusted so that any kernels carried over with the blast shall fall on one side of it, while the dust and shells fall on the other. The machine illustrated can deal with 7½ cwt. of seed per hour, and absorbs in its driving about 3 h.p.

CHAPTER VI

SOME SPECIAL FORMS OF REDUCTION MACHINERY

THE preceding chapters should have given the reader some idea of how certain important oil-bearing vegetable substances are prepared for pressing, and of the design and working of the special machinery used for this preparation. We have by no means exhausted this section of our subject, but we must now conclude it by describing the construction of a few additional and more or less specialised machines used for the reduction of various prepared or unprepared seeds, fruit, etc., to the form of meal.

HORIZONTAL SEED ROLLS.

The rolls employed for reducing copra, palm kernels, linseed, cotton seed, castor seed, and so on, are, generally speaking, of much the same design whatever the material treated may be. In Chapter III. we illustrated and described several typical examples. In Fig. 26 we give a view of a special set of rolls constructed by Robert Middleton & Co., Sheepscar Foundry, Leeds, and intended particularly for crushing castor seeds and similar material. The rolls, two in number, are in this instance arranged side by side and not vertically, as they so frequently are. They are of chilled or other hard cast iron, lightly fluted with spirals, and measure 16 in. in diameter by 30 in. in length. Their distance apart is adjustable within limits. One of the rolls runs in fixed bearings, while the bearings of the other are slidable and are acted upon by strong springs which permit the rolls to open if the feed is too heavy, or if any hard foreign substance is encountered in the seed. The rolls are driven by heavy cast-iron gearing and run at from 80 to 100 revolutions per minute. A steel scraper is provided for each roll and is held up to its work by means of a pair of forged levers and cast-iron weights. The cast-iron hopper situated over the opening between the two rolls is fitted with the usual power-driven feed roller and hand-regulated feed shutter. About 10 tons of material can be treated per day of ten hours with these rolls. To drive them requires about 4 h.p. Similar rolls are made by Messrs. Middleton for treating copra, palm kernels, etc., but for such heavy material two pairs of rolls, one above the other, are provided.

While it is generally true that rolls such as the above, and those previously described, are in extensive employment for reducing oil-bearing seeds, etc., to the form of meal, it is to be noted that various other forms of crushing or disintegrating machinery are made and are in employment. That efforts should be made to provide alternative means of reducing seed to meal is to be expected, for the practice of using rolls involves, more especially in the case of heavy material such as copra and palm kernels, the expenditure of a considerable amount of power, and results in the space occupied by the reducing plant being greater perhaps than it need be. We have already illustrated one form of alternative to a set of rolls, namely, the preliminary breaking machine made by Messrs. Manlove, Alliott and shown in Fig. 3, Chapter III. Four other alternatives will now be referred to.

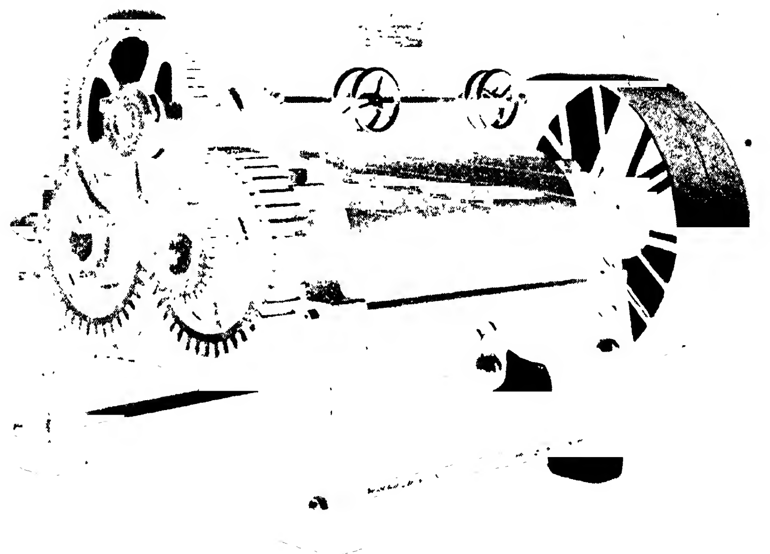


FIG. 26.—Horizontal Seed Rolls—Robert Middleton.

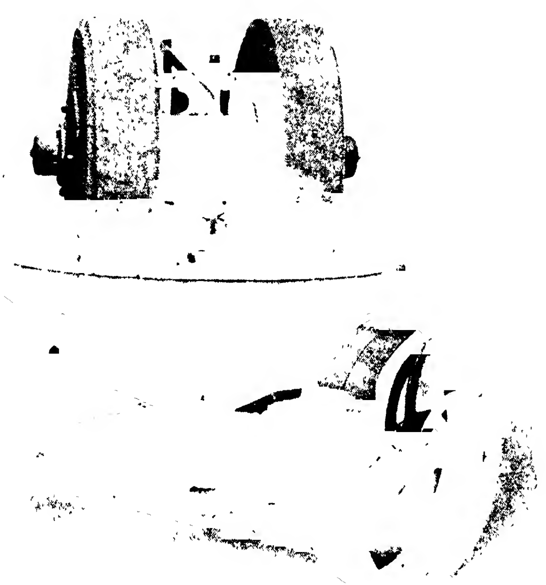


FIG. 27.—Edge Runner—Robert Middleton.

Edge Runners.

The first of these, the edge runner, has long been in use for reducing oil seeds, fruit, etc., to meal suitable for pressing. As employed at the oil mill, the edge runner

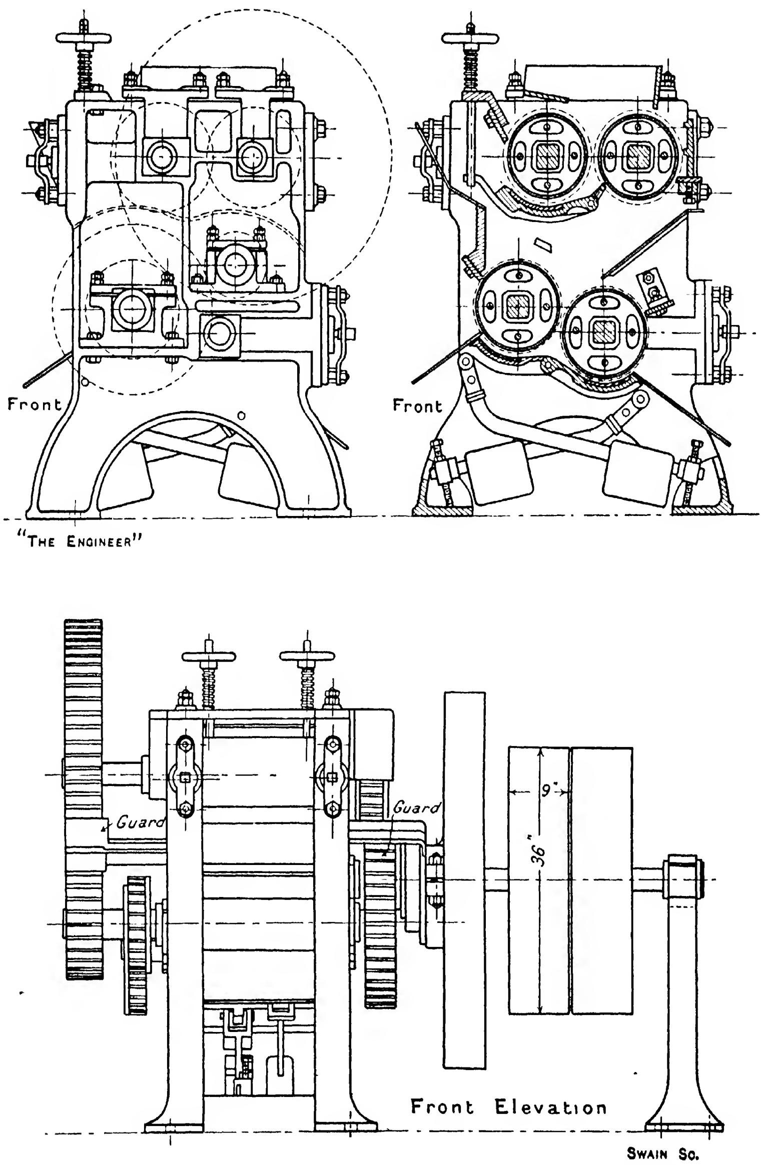


Fig. 28.—Special Grinding Mill with Concave Plates—Rose, Downs & Thompson.

differs in no essential respect from the form used in many other industries. Edge runners are to be found in employment in chocolate and confectionery factories, for mixing mortar, in paper mills, under the name of "kollergangs," for reducing "broke"

paper to pulp, and elsewhere. An oil mill edge runner, as constructed by Robert Middleton & Co., of Leeds, is illustrated in Fig. 27. It consists, as usual, of two stones mounted on an axle, which is rotated in a horizontal plane by means of a vertical shaft, which is set somewhat nearer one of the stones than the other. In the case illustrated the stones are 4 ft. in diameter and 12 in. wide. The driving pulley runs at about 100 revolutions per minute, and rotates the vertical spindle through bevel reduction gearing at about 20 revolutions per minute. The action of the runner depends as usual upon the slipping which takes place between the edges of the stones

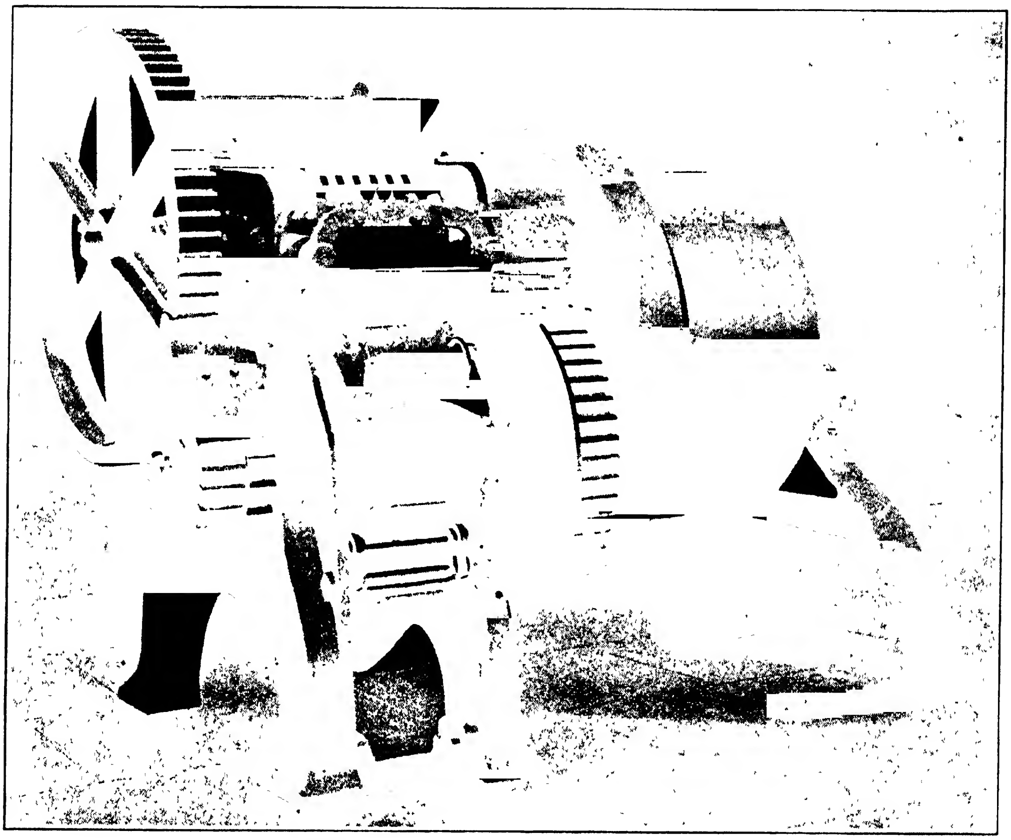


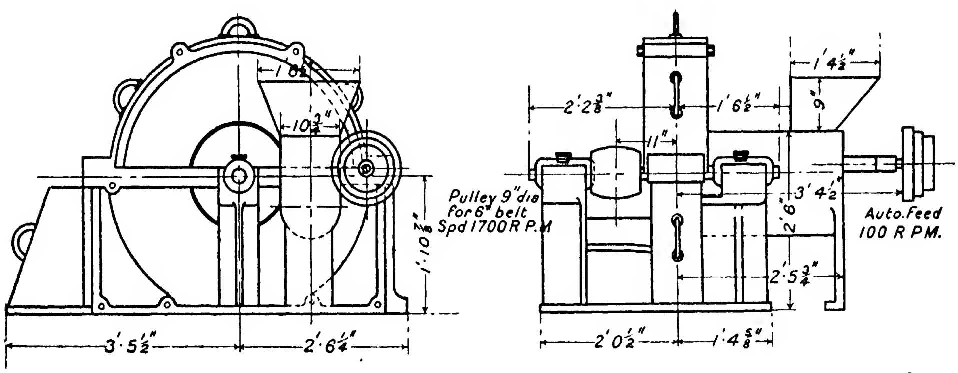
FIG. 29.—Reducing Mill and Cake Breaker—Robert Middleton.

and the bed stone on which they run. A pair of sweepers is carried round with the vertical shaft. These sweepers can be adjusted to guide the material beneath the stones or to turn it outwards so as to discharge it through an outlet door in the pan surrounding the bed stone. In the case of machines intended for reducing linseed, etc., the runners are commonly made of selected hard grit stone. For reducing olives, a common application of the edge runner, they are usually made of granite. The edge runner illustrated was designed to deal with about 4 tons of olives per day, and absorbs in its driving about 8 h.p.

Other alternatives to the ordinary rolls take the form of special grinding or reducing mills and disintegrators.

Grinding and Reducing Mills.

A special form of grinding mill suitable among other things for finely grinding palm kernels and copra, is illustrated in Fig. 28. This machine is made by Rose, Downs & Thompson, Ltd., of Hull. It contains two pairs of finely fluted rollers, the bearings of which are acted upon horizontally by springs which permit the rollers to "give and take" with the feed. The material is fed from the hopper at the top to the opening between the first pair of rolls, and thence passes through an intermediate hopper to the second pair of rolls. The special feature of the mill lies in the provision, beneath one of the first pair of rolls and beneath both of the lower pair, of concave plates between which and the associated roller the material must pass before it proceeds farther on its course. The position of the upper concave plate is adjusted by means of two screwed rods provided with springs and hand wheels. The two lower plates are similarly held up to their work and adjusted by means of weighted levers. The discharge of the material takes place simultaneously from each side of the lower pair



"The Engineer" Swain Sc.

Fig. 30 —Disintegrator—Rose, Downs & Thompson.

of rolls. The machine illustrated has an output of from 30 to 40 cwt. of palm kernels or copra per hour. Its belt pulley runs at 300 revolutions per minute. About 24 b.h.p. is required to drive it. Its rolls are 16 in. long and 12 in. in diameter.

The object of fitting the concave plates beneath the rolls of this machine is clear. Each concave is in its effect equivalent to the provision of an additional roll or pair of rolls. Thus, in the case of the machine illustrated in Fig. 28, the material is reduced to the same extent as it would be if it were passed between four pairs of ordinary rolls without concaves. Although the power consumed may not be less to any extent worth considering, the concave arrangement results in a considerable saving in the space occupied by the machine and economises in capital expenditure and upkeep charges.

Another form of reducing mill with concaves, made in this case by Robert Middleton & Co., Leeds, is shown in Fig. 29. This mill is fitted with two pairs of toothed rolls built up of plates keyed and bolted together on mild steel shafts. The degree to which the teeth of each pair of rolls intermesh is adjustable to give the required fineness to the material being treated. The rolls of each pair run at differential speeds, about 60 and 80 revolutions per minute, so that the action is partly a tearing and partly a crushing one. In addition, the difference in speeds avoids any tendency of the rolls to become clogged with the material being reduced. The machine is made in two forms. In one, the lighter, a concave plate, hinged and adjustable, is fitted

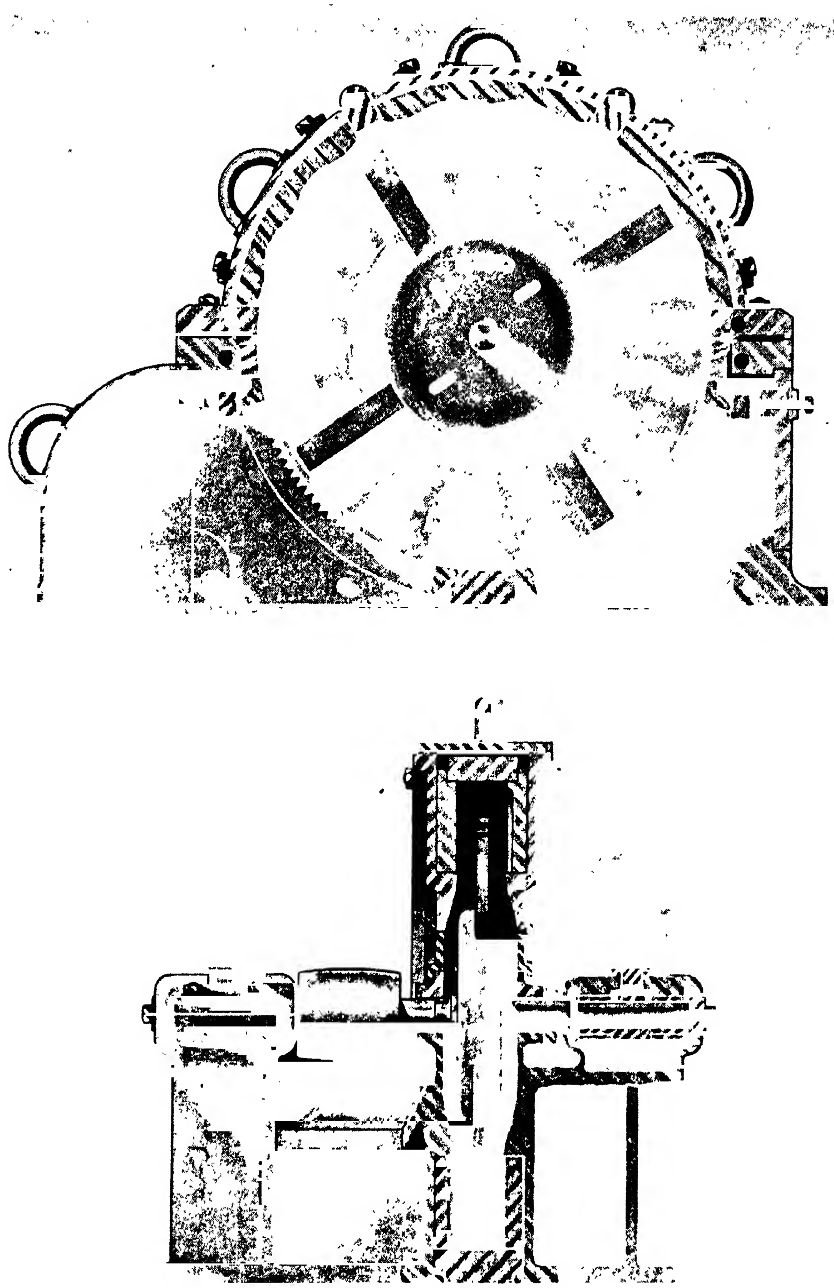


FIG. 31.—Disintegrator, showing Beater Arms, Waved Plates, and Bar Screen.

beneath one of the lower pair of rolls. In the other form, intended for an increased output, three concave plates are provided. The machine illustrated is capable of grinding a ton of copra per day. Its driving absorbs about 5 h.p. The belt pulley runs at 250 revolutions.

Disintegrators.

Quite a different type of reducing machine for copra, palm kernels, and so on, made by Rose, Downs & Thompson, Ltd., is illustrated in Figs. 30 and 31. This machine is known as a disintegrator. It comprises a circular casing within which there revolves at a high speed a disc carrying four flat-bar beater arms. Each side of the case interior is fitted with chilled iron segmental liners the surface of which is waved. Three similarly waved chilled iron liners are disposed round the top half of the periphery of the case, while the lower half of the periphery is formed by a bar screen in two parts. The material to be treated is fed into the casing from a hopper, the feed being sometimes, as in Fig. 30, assisted by a power-driven worm. Falling on to the extremity of the beater arms, the material is thrown violently against the chilled iron waved plates or against the screen until it is reduced by the blows which it thus suffers to a degree of fineness sufficient to enable it to pass through between the bars of the screen. It will be noticed that the liner and screen segments are designed to be easily replaceable. The size of machine illustrated in Fig. 30 has an output of 24 cwt. of copra or such like material per hour. The beater shaft runs at 1,700 revolutions per minute. Twenty-eight brake horse-power is absorbed in driving the machine.

Special Uses for these Machines.

The special forms of reducing machinery described in this chapter, with the exception perhaps of the rolls illustrated in Fig. 26, can be and are used for other purposes than that of reducing vegetable oil-bearing substances wholly or partially to the form of meal suitable for pressing. Thus the disintegrator just described has been, we are informed, successfully applied to the reduction of over 250 different kinds of material ranging from broken crockery, iron turnings and wood shavings to coal, shoddy, cork and bones. With such uses we are not here concerned, but it may be noted that, even in the oil mill, alternative uses for the machinery described are found. For example, oil cakes from which it is desired to recover a "second expression" oil may be once more reduced to the form of meal by means of the reducing mill illustrated in Fig. 29. When used thus as a cake breaker, this machine can deal with about 3 tons of material per hour. Again, the cakes taken from the press nearly always have their edges well saturated with oil, for it is next to impossible to prevent some of the oil from lingering behind at the edges of the cake. Partly to improve the appearance of the cake, but chiefly to avoid wasting oil, these edges are trimmed off in special machines. The material thus recovered is reduced again to the form of meal and returned to the kettle for mixture with fresh meal. A suitable machine for reducing the oily edge parings to meal is the edge runner, shown in Fig. 27. Finally, in the manufacture of compound feeding cakes—a process sometimes carried on at the oil mill and sometimes in an entirely separate establishment devoted solely to the work—the special grinding mill shown in Fig. 28, or the disintegrator, Figs. 30 and 31, is of great service. The term "compound cake" has been used to denote a re-formed feeding cake made from a mixture of genuine press cake and of extracted meal, that is to say, of the meal left after seed has been extracted with chemical solvents. As commonly used, however—at least in this country—the words denote a re-formed cake, made from pure linseed, cotton seed or other press cake and one or more other ingredients, the addition of which is regarded as increasing the food value of the pure cake. Among such added materials may be mentioned locust beans, rice, peas, sugar, ginger, lentils, salt, etc., besides other press cakes such as cocoa-nut or palmnut cake. For reducing these materials to the required degree of fineness preparatory to adding them to the pure cake material the machines mentioned can conveniently be employed.

CHAPTER VII

MEAL KETTLES, RECEIVING PANS AND MOULDING MACHINES

WE have now described the special preparatory machinery in use for the preliminary treatment of certain typical oil-bearing vegetable substances, namely, copra, linseed, palm fruit, palm kernels, cotton seed and castor seed. The material, whatever its original form, is, as delivered from the preparatory machinery so far described, in the form of "meal." The next step in the process is to heat this meal—if, that is to say, the oil is, as it more usually is than not, to be expressed hot. The heating of the meal is commonly conducted in a steam "kettle," and is, of course, carried out immediately before the pressing takes place, so that the material when placed in the press may still be hot.

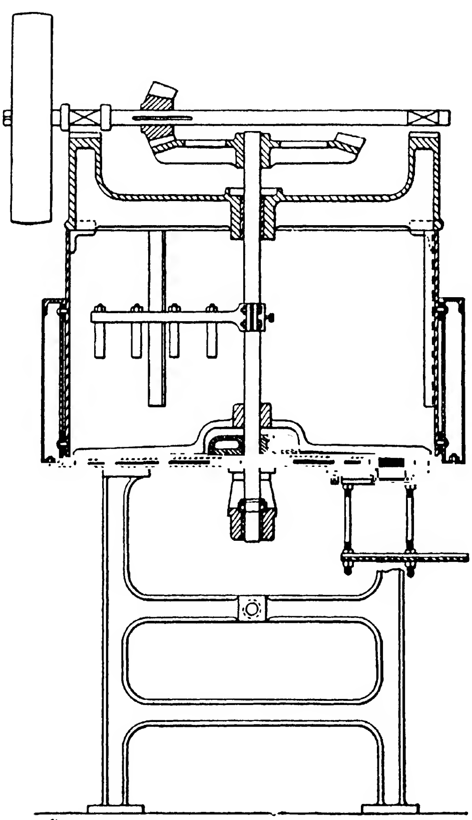


FIG. 32.—Meal Kettle—Manlove, Alliott.

The heating of the meal greatly facilitates the expression of the oil from it, for it results in the rupturing of the minute vessels or sacs in which the oil is naturally contained within the meal. In so far as it does this it directly relieves the press of a corresponding amount of work. In addition, the heating of the meal naturally reduces the viscosity of the oil, and therefore renders its flow easier. A third effect of heating is also to be noted. Any albuminous matter present in the meal will be coagulated or solidified during the heating process, and will thereby be largely retained within the cake left in the press and will not flow away with the oil. The heating proper of the meal is effected usually by means of a steam jacket surrounding the kettle. Frequently, it will be found that a little steam is, in addition, admitted direct to the meal when in the kettle. The object of this, however, is not so much to heat the meal as to "temper" it so as further to facilitate the flow of oil.

The meal is withdrawn from the kettle in convenient amounts, and is immediately rough-moulded in a machine into rectangular or other shaped slabs or cakes of a size suitable for the press in use. As quickly as made these cakes are taken to the press,

so that they may be pressed before they lose their heat. The cakes, after pressing, are, of course, those known to farmers. They are very commonly either oblong or oval, and, as trimmed, vary in size from about 21 in. to 26 in. long by 11 in. to 13 in. wide.

Meal Kettles.

A typical meal-heating kettle, made by Manlove, Alliott & Co., Ltd., of Nottingham, is illustrated in Fig. 32. The kettle is a cylindrical iron vessel jacketed round its side and bottom for heating steam at a pressure of about 75 lb. and containing power-driven stirring gear. The steam jacket round the side is covered with a layer of non-conducting material, enclosed within a sheet metal casing. The top of the kettle is open, except for the cast-iron bridge which spans it and carries the driving gear. The bottom of the kettle with its steam jacket is made readily detachable from the rest for renewal purposes, as this part is that which is most subjected to wear. The thorough agitation of the meal in the kettle is necessary, not only to attain uniform heating, but also to prevent it becoming discoloured.

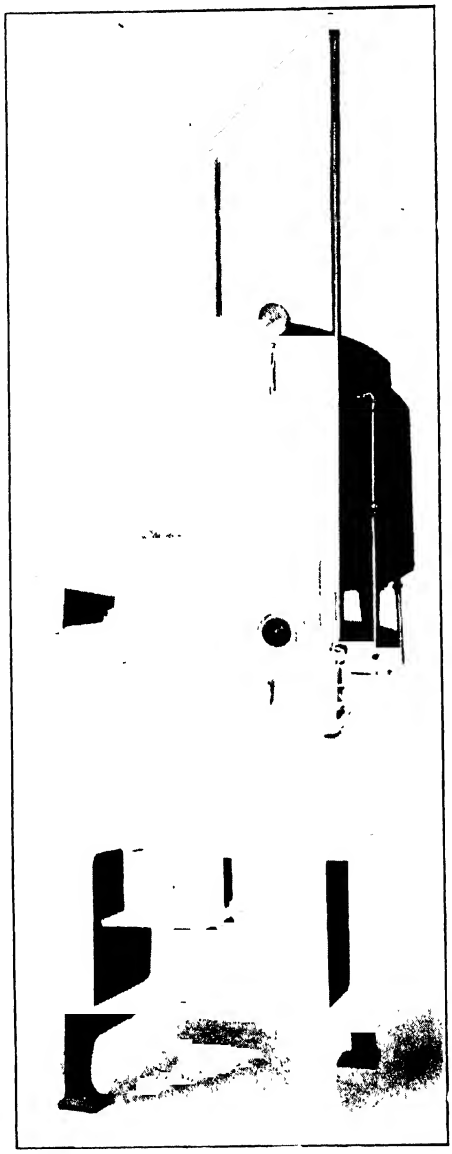


Fig. 33.—Double Kettle—Manlove, Alliott.

A feature of the apparatus illustrated in Fig. 32 lies in the fact that the vertical agitator shaft is carried through the bottom of the kettle and is supported on an external ball thrust bearing. This considerably reduces the power required to drive the agitator. It will be noticed that a perforated box surrounds the agitator shaft where it passes through the kettle bottom. This is for the admission of saturated steam to the mass in the kettle. The admission of such steam results in the moistening or "tempering" of the meal, and facilitates the subsequent flow of oil from it. The means provided for withdrawing a charge of meal from the kettle and delivering it to the preliminary cake moulding machine can be gathered from Figs. 32 and 33. At the foot of the kettle, an orifice, opened and closed by a shutter, is formed. Beneath this, a flat board is hung whereon a strickling box—see Fig. 33—open at the top and bottom, can be run. The shutter is arranged to be automatically opened when the strickling box is pushed beneath it, and closed when it is withdrawn. The strickling

box with its charge is pulled on to the table of the moulding machine—see Fig. 34. The agitator shaft carries at its foot a pair of arms, which help to pass the meal from the kettle through the orifice into the strickling box.

These kettles are made in various sizes, ranging, say, from 1 ft. 8 in. diameter by 1 ft. 3 in. deep to 6 ft. diameter by 2 ft. 8 in. deep. In some instances, two are arranged, one on top of the other. Such a pair, made by Messrs. Manlove, Alliott, is shown in Fig. 33. This arrangement not only simplifies the driving gear required, but also facilitates the working and ensures that the meal delivered to the presses

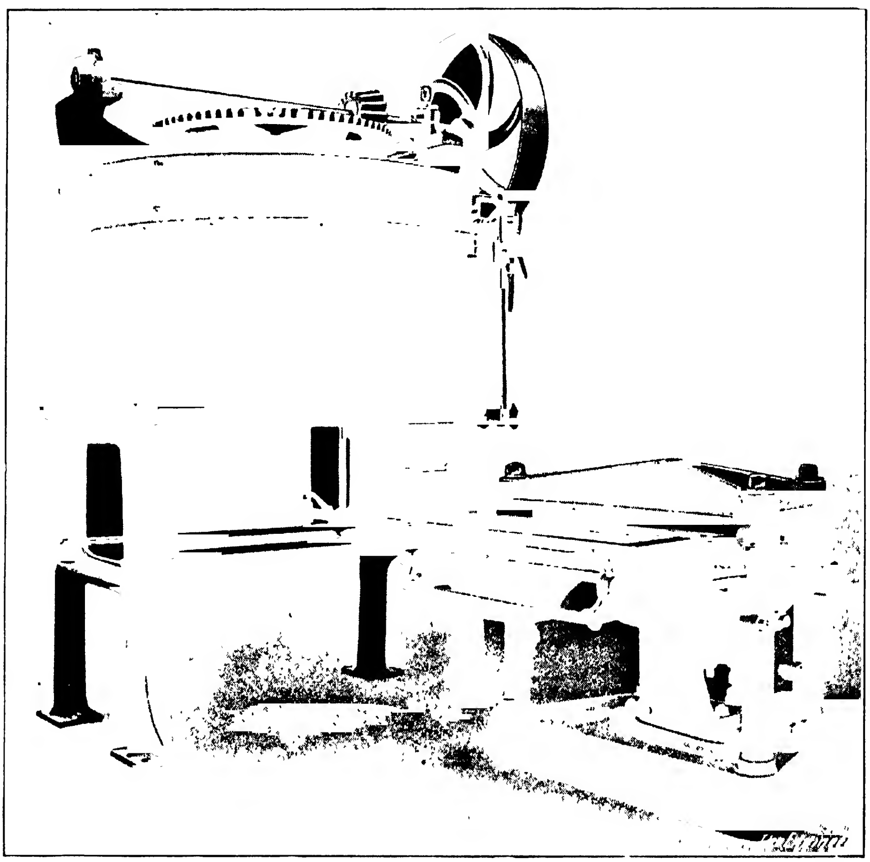


FIG. 34.—Kettle and Moulding Machine - Robert Middleton.

shall be at an even temperature. Both kettles are steam jacketed. The upper one receives the meal in the first instance. Having been heated to a certain degree, the meal is discharged from the upper to the lower kettle through a slide in the bottom of the former. When heated, ready for the press, it is withdrawn from the latter in the usual way. Both kettles contain agitating gear.

The engraving Fig. 34 shows a meal-heating kettle and moulding machine made by Robert Middleton & Co., Leeds. The view is here given, as it shows very clearly the relative situations in use of the kettle and the moulding machine. The driving pulley of this kettle runs at about 130 revolutions and the agitator shaft at about 30 revolutions. Some 3 h.p. or so is consumed in driving it.

RECEIVING PANS.

When the meal is to be pressed cold a heating kettle is, of course, not require It is convenient, however, to provide a "receiving pan" for the meal, from whic the moulding machines may draw their supply. The kettle itself acts as such a receivir

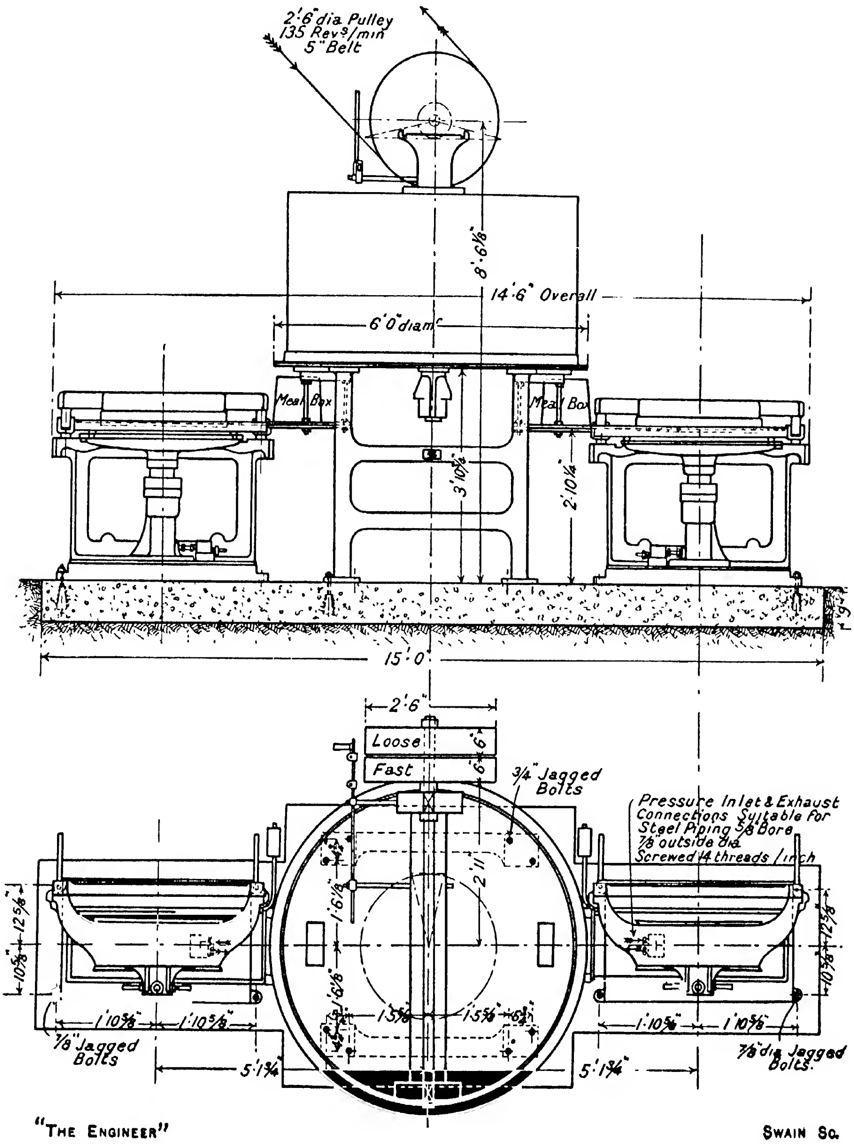


FIG. 35.—Receiving Pan and Moulding Machines—Manlove, Alliott.

pan when hot pressing is being followed, and with the steam shut off from the jacket may still so serve when cold pressing is adopted. If cold pressing is, however, th rule rather than the exception, it is clearly not desirable to spend money on a kettl when a simpler, cheaper receptacle will serve the purpose equally well. The arrange-

ment of a 5 ft. 6 in. receiving pan, by Manlove, Alliott & Co., Ltd., is given in Fig. 35. This pan may be described as a kettle without the steam jackets and other heating adjuncts. It contains a modified form of stirring gear, the purpose of which is simply to ensure proper delivery of the meal to the outlets at the foot of the vessel. There are two such outlets in this example, each controlled by an independent shutter and meal box, and each serving a separate moulding machine.

Meal-Moulding Machines.

We now pass on to describe the construction and working of the meal-moulding machines. The object of these machines is to press the meal into the form of a cake, so as to facilitate the filling of the main presses. The moulding pressure employed must not exceed that at which oil will commence to flow from the meal. The nearer it approaches this amount, however, the less will be the work required subsequently of the main press; while the greater the preliminary compression of the meal in the moulding machine, the less will be the height of the main press required for a given output. The moulding machine must be reliable and quick in its action. As each cake is formed in it, the cake is taken away to the press and a succeeding cake moulded. The press may hold sixteen or more cakes, and not till these cakes are all in place can the pressing be commenced. The moulding machine must work regularly and quickly, for it is not desirable to have a considerable difference in the temperatures of the first and last cakes placed in the press. Where cold pressing is in force, the moulding machine can, of course, be worked more leisurely than is desirable with hot meal.

Moulding machines are obtainable in various forms. In general, they are operated by hydraulic pressure taken from the accumulators—the low-pressure accumulator, if there be such—provided for the working of the main presses. They are sometimes designed to be operated by hand, the necessary force being applied through a screw. Occasionally they are worked by steam pressure.

A hydraulic moulding machine of a usual type, made by Manlove, Alliott & Co., Ltd., is illustrated in Fig. 36. As will have been gathered already, the moulding machine is placed close beside the kettle so that the strickling box filled with meal may be readily drawn over on to it. In the case of the machine shown in Fig. 36, the kettle would be arranged on the right-hand side.

The strickling box leaving the supporting board of the kettle passes on to the hard-wood block or frame shown at the front of the machine, being guided thereon by the upstanding edges of the block. The block is counterbalanced and is hinged to turn upwards and backwards. In the view given it is resting upon a sliding table, which for the time being is in its extreme forward position. Before the strickling box is pulled across, the wood block is lifted up and a tray of sheet steel is placed on top of the sliding table. Over this tray is placed a length of "press bagging," a woven material, the nature and function of which will be explained in due course. The wood block is then lowered back on to the sliding table and the strickling box run out so as to fill the hole in the block with meal. On hinging back the wood block, a gauged amount of meal is thus left standing on the tray and press bagging. The bagging is of the same width as the cake to be formed, and of about twice the length. The two ends are folded over the top of the meal, and the sliding table, with the tray, bagging and meal, is pushed forward over the hydraulic ram. The sliding table supports the tray round three of its edges. When the table is pushed over, it moves a lever operating the valve of the hydraulic ram, so causing the head of the latter to rise against the underside of the tray, lift it off the table, and compress the meal against the fixed head of the machine. The table meanwhile is withdrawn and made ready for moulding

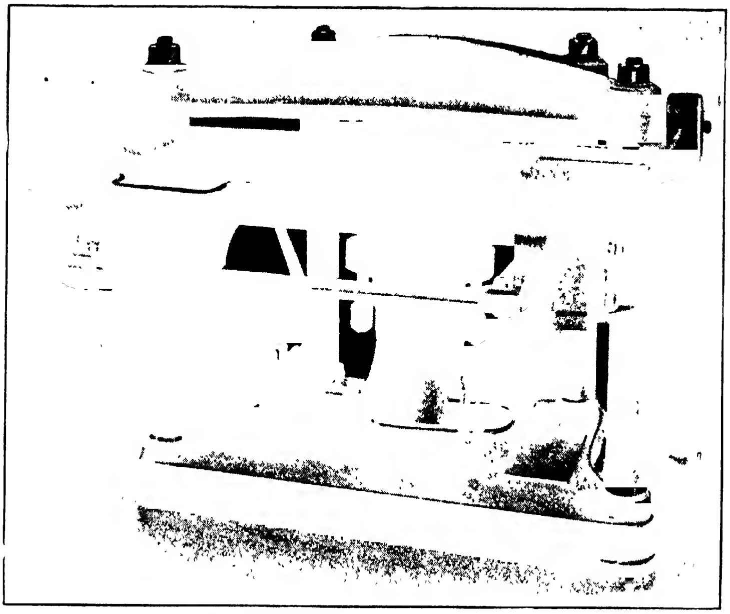


FIG. 36.—Ordinary Form of Hydraulic Moulding Machine Manlove, Alliott.

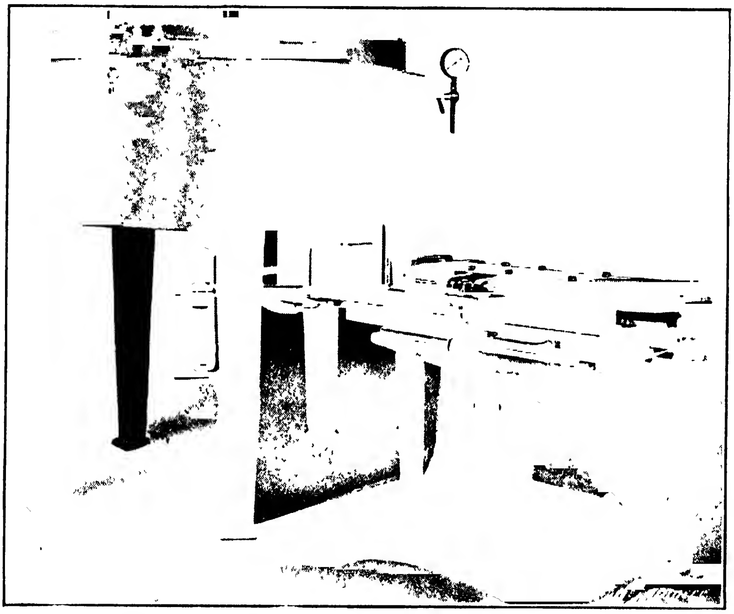


FIG. 37.—Special Form of Hydraulic Moulding Machine—Manlove, Alliott.

a second cake. The ram is lowered by operating the valve lever by hand, and the cake and bagging supported on the tray are removed to the presses. The pressure employed in the hydraulic cylinder is from 500 lb. to 600 lb. per square inch.

The above form of machine is thought by some to suffer from a disadvantage

in that the meal during the swinging up of the wood block, and during the movement forward on to the ram, is liable to be shaken with the consequent production of a misformed cake. A moulding machine designed to overcome this objection, made by Messrs. Manlove, Alliott, is shown in Fig. 37 and also in Fig. 35. In this case, the head of the machine is hinged so that it may be swung over and thus permit the meal to be moulded while still supported round the four edges by the wooden frame or block. The tray and bagging are placed directly on top of the ram head, the wood frame is swung down and the strickling box is advanced to fill the frame with meal. The frame is then lifted up and again lowered after the ends of the bagging have been turned over. The head is thereafter lowered so as to enter the hole in the wood frame, and is locked in this position by means of the spring rod shown at the front of the machine in Fig. 37. Pressure is then applied within the hydraulic cylinder to compress the tray, bagging and meal against the machine head. The wooden frame, being pivoted, lifts slightly while this is occurring.

Automatic Moulding Machines.

Quick, easy operation being very desirable in a meal-moulding machine, it is natural to find that efforts have been directed towards making the action more automatic than it is in the machines of the type described above.

An automatic—more correctly a semi-automatic—meal-moulding machine, made by Rose, Downs & Thompson, Ltd., is illustrated in Figs. 38 and 38A. This machine consists of two moving parts, namely a horizontally sliding measuring box A and a vertically sliding moulding box B. The movement of the boxes is effected hydraulically, and is controlled from the handles C and D respectively. E indicates the lower face of the heating kettle. The ends of the moulding box B are open, so that the usual tray and bagging may be slipped into the box. With these in position, the measuring box A is moved into its extreme left-hand position and a charge of meal is withdrawn from the kettle and is gathered into the hole F in the box. The measuring box is then moved over to the right. Any surplus meal standing more than ¼ in. above the level of the top of the measuring box is swept off by the edge of the oblong boss G on the entablature H. Such surplus meal is carried back on. to the plain rear portion of the measuring box, and thence can be swept into the hole F on the next stroke. The meal in the hole F, as the measuring box advances, falls into the moulding box, where it rests on top of the tray and bagging already there. The measuring box is now returned to its extreme left-hand position, the bagging is folded over and the moulding box is raised so as to compress the meal against the boss G. Care, as we have already said, is required to see that the pressing is not carried so far that oil will be forced from the meal. This effect is secured in this machine by limiting the upward movement of the moulding box by means of the nuts and washers on the ends of two rods J attached to it.

The machine is semi-automatic in so far as the movement of the measuring box is concerned. The right-hand end of the hydraulic cylinder operating this box is constantly open to hydraulic pressure through the pipe K. By reason of the presence of the piston-rod, the working area on this side of the piston is less than it is on the other. Hence, if the same hydraulic pressure is admitted to both sides of the piston, the measuring box will be moved to the right. When the box approaches its extreme right-hand position, a gudgeon L attached to it strikes the end of a lever M coupled up with the handle C and the valve N which this handle controls. The left-hand end of the hydraulic cylinder is thus set to exhaust, and the measuring box automatically moves back again to the left. The moulding box must not, of course, be raised until

the measuring box is fully out of the way. To prevent accidents, the end of the rod on which the handle D is fixed is formed with a cam incline on which the roller of a

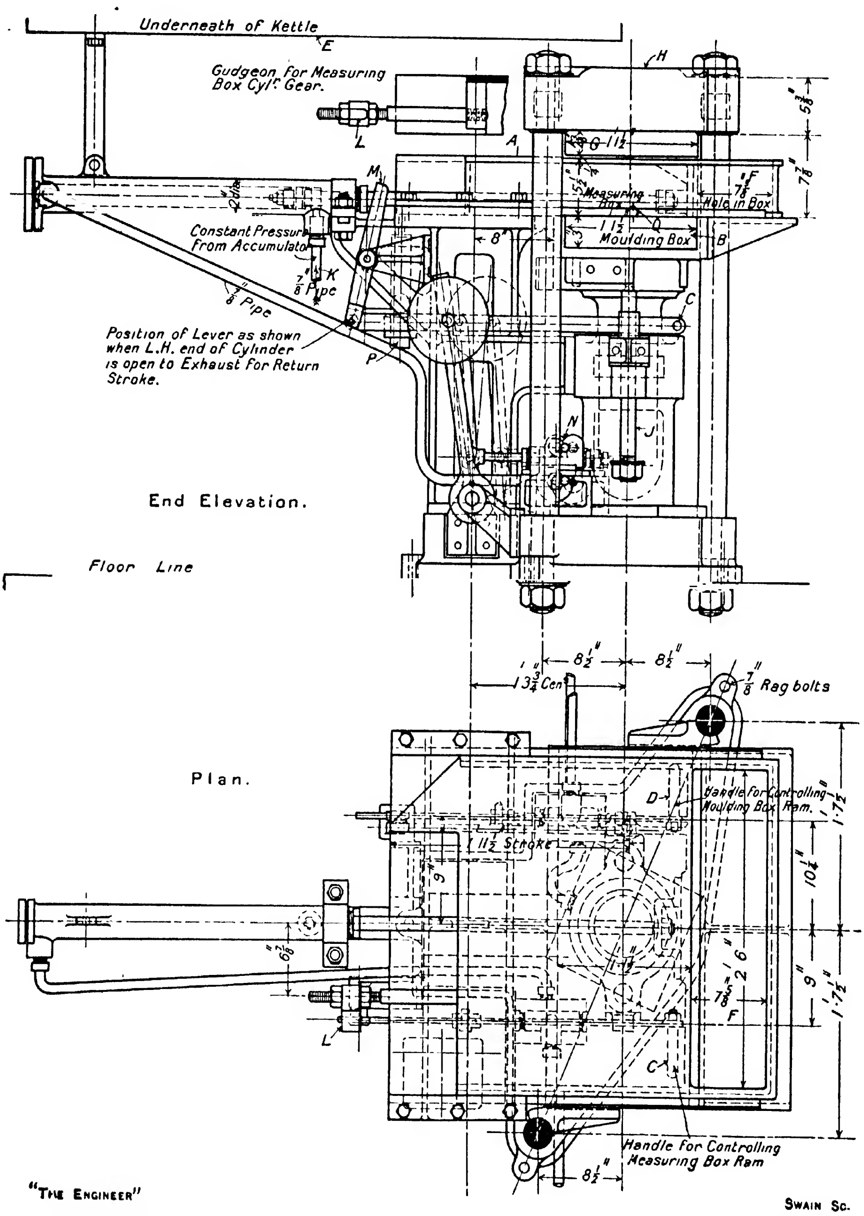


Fig. 38.—Semi-Automatic Moulding Machine—Rose, Downs & Thompson (for front elevation see Fig. 38a).

plunger P operates. To fit the top end of this plunger a hole is formed at Q on the underside of the measuring box. The handle D cannot thus be moved until the measuring box occupies its extreme left-hand position.

The machine illustrated is capable of rough-moulding the meal to meet the require-

ments of eight 16-cake presses. It is worked from the low-pressure accumulator installed for the presses or by any other source of hydraulic power at a pressure of about 700 lb. per square inch. The facts that its action is automatic to the extent indicated, and that it dispenses with the use of a hinged wood frame, make it, it is claimed, especially suitable for installation where labour is unskilled and result in its capacity being twice that of a corresponding moulding machine of the ordinary pattern.

Press Bagging.

We have referred above to the "press bagging," in which the cakes as moulded are wrapped before being placed in the press. The trays used during the moulding

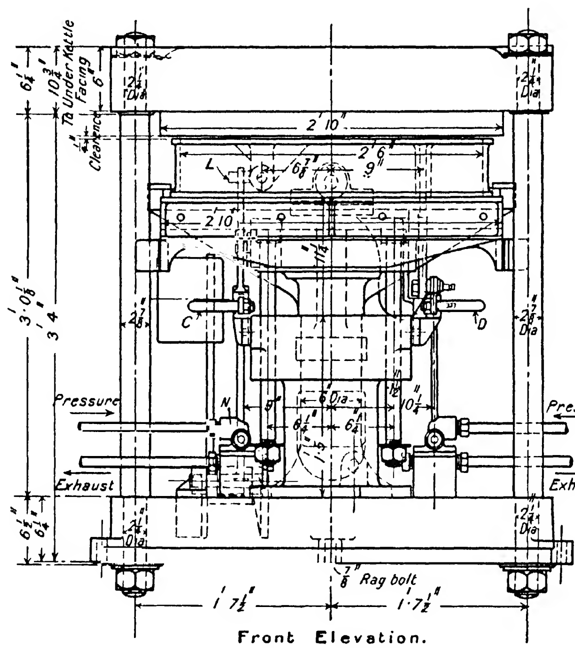


Fig. 38a.—Semi-Automatic Moulding Machine—Rose, Downs & Thompson.

operation are simply for supporting the formed cake while it is being carried to and placed in the press. They are not inserted in the press with the cake. The bagging, on the other hand, is so inserted, and is not stripped from the cake until the pressing is completed. This bagging is made of wool, camel-hair, or alpaca, the first-named being the generally preferred material. It is commonly obtainable in different widths, varying from 10 in. to $13\frac{1}{2}$ in. and weighing respectively $12\frac{1}{2}$ oz. to 17 oz. per yard run. It is not simply a wrapping for the cake. It fulfils in reality a most important function, for without its presence the yield of oil from the meal would be considerably reduced. Were its use discarded, the flow of oil from the meal would cease as soon as the applied pressure consolidated the meal and closed up the interstices through which the first portion of the oil might run. The oil would, in fact, have to travel anything up to half the *length* of the cake through the meal itself. With the bagging

in use an easy passage outwards is provided for the oil. The oil, in order to reach the bagging, does not require to travel through the meal for a greater distance than half the *thickness* of the cake.

The expression "bagging" arose from the fact that formerly, before moulding machines were introduced, the meal was filled into actual bags which were placed without further work into the press. This method of working suffered from all the disadvantages which the preliminary formation of a partially compressed cake of even thickness and uniform size is intended to overcome. The method is still occasionally employed, notably in the case of manually operated presses and in other small installations specially intended for export to oil-seed-producing areas.

CHAPTER VIII

OIL PRESSES—ANGLO-AMERICAN TYPE

As we explained in Chapter I., vegetable oils are extracted from the properly prepared oil-bearing substances in either of two ways, one being by the application of pressure, and the other being by the use of chemical solvents. With the latter method we shall deal in a succeeding chapter. The former, the pressure method, and the machinery required for it, will be dealt with first, as it is undoubtedly true that, for the present, more oil is recovered by it than by the chemical solvent method.

Development of the Oil Press.

A word may perhaps be said as to the historical development of the oil press. The ancients used presses operated by wedges or levers. The Greeks and Romans, in the recovery of olive oil, employed screw presses, which followed closely in design the usual form of wine press. The screw type of press persisted in use for many centuries, and may still be said to be in employment in the shape of certain small hand-power presses having a capacity of 8 lb. to 10 lb. of seed per charge, and supplied for trial and other purposes. In the seventeenth century the Dutch "stamper" press was invented. Although in principle it was but a revival of the wedge press of the ancients, it played an important part in the development of the industry, persisting in use even some considerable time after the development and application of the hydraulic press. The Dutch press consisted of an oblong wooden or cast-iron box containing a perforated double bottom. A bag filled with meal was placed at each end of the box, between perforated iron plates. The space between the two bags was filled up with wooden blocks and wedges. Over the box was erected a framework on which was swung a balk of timber some 16 ft. long by 8 in. or so square. This balk was lifted and allowed to fall on one of the wedges in the box by means of a revolving shaft. About fifteen blows a minute were delivered on to the wedge, the height of fall of the balk being about 2 ft. A blow delivered on a second and inverted wedge loosened the blocks and bags in the box when the pressing was completed.

The development by Bramah of the hydraulic press received application in the oil-seed-crushing industry early in the nineteenth century. The first hydraulic oil presses were little more than Dutch presses in which hydraulic power was substituted for that obtained from wedges and a falling weight. Horizontal oil presses continued in use for some considerable time, but the economy of floor space and other advantages attendant upon a vertical position were early recognised, and development followed in that direction. The earlier vertical presses were designed to deal with the oil meal in bags, just as in the case of the Dutch press. The presses were provided with two tubs or circular boxes of metal, one, perforated all over, being placed within the other, which was used to catch the expressed oil. The bags of meal, with a metal plate between each, were deposited within the inner, perforated box, and the whole, resting on the head of the hydraulic ram, was forced upwards against the overhead entablature of the press, a circular boss on the underside of which entered the perforated box and

exercised the necessary reaction on the meal bags. It was soon found that this method of working could be improved upon if each bag of meal were pressed in a separate box, and as a result the "box press," with four or so separate seed boxes, came into favour.

Modern Hydraulic Presses.

Up to this point it was universally the custom to press the meal in bags. These bags were a source of trouble and expense, for they were readily damaged, and had constantly to be renewed. Their employment, however, was dictated largely by the convenience which they provided in charging the press with meal. With the development of the meal-moulding or forming machine a new direction was given to the evolution of the oil press. The moulding machine permitted the meal to be handled and placed in the press without the use of bags. The cakes, rough formed, had only to be wrapped in press cloths and taken to the press on a tray. We have already explained that the function of the press cloths is, not only to provide a filtering medium, but also to establish a passage outwards for the oil when the meal closes up under pressure. This function was, of course, also fulfilled by the old-fashioned bags, but in contrast with these the press cloths are far less readily damaged, and can be renewed simply by cutting off lengths from a roll of cloth. With this development, boxes were no longer required in the press, and were replaced by a series of horizontal plates, between which the rough-formed cakes could be placed and pressed. This system of press, the Anglo-American, as it is universally called, was introduced into this country in 1873 by Rose, Downs & Thompson, Ltd., of Hull, and was at first applied only to the crushing of linseed and similar smalloil-bearing seeds. To-day it is in extensive employment for extracting oil from many kinds of seeds, nuts, etc. In a common size it is provided with plates sufficient to make sixteen cakes at one pressing, representing a total charge of, say, 320 lb. of crushed seed.

In a still later type of oil press, known as the "cage press," something of a reversion to the earliest form of box press is to be observed. The cage press derives its name from the fact that, in place of the horizontal plates of the Anglo-American system, there is substituted a circular-sectioned cage built up of finely spaced upright bars. Inside this cage the meal is placed in layers separated from one another by means of press cloths and discs of metal. The cakes turned out by this form of press are circular. The system has recently come into extensive use, and is particularly adapted for pressing castor seed, copra and other substances of a very oily nature, which are commonly pressed twice. These two types of press, the Anglo-American and the cage, at present hold the field. Typical examples of each will now be described and illustrated.

Typical Anglo-American Presses.

In Plate I. we reproduce a drawing—kindly prepared for us by Manlove, Alliott & Co., Ltd., of Nottingham—showing an Anglo-American oil press and some of its details. This example consists of a cast iron head and bottom, united by four forged steel columns having buttress-threaded nuts at each end, a cast steel cylinder resting within the bottom casting, and a hollow cast-iron ram suppoiting a cast-iron table or head. The bottom casting is flanged all round to form a tray in which the expressed oil is caught. Between the top and bottom castings fifteen steel press plates are arranged horizontally. These plates provide spaces for sixteen cakes, each space, when the plates are fully dropped, being 2¾ in. in depth. Each plate is hung from the one above by means of four oval mild steel links slipped over square-headed studs screwed into the plate edges, the topmost plate of all being hung similarly from the

top casting. To the inner side of each of the four columns of the press a flat, square-edged runner or guide is pinned. The width of the plates is a loose fit between these guides, while square-headed studs, screwed into the plate edges, engage the outer faces of the guides, and prevent the plates moving lengthwise. This method of supporting the plates secures the required condition, namely, that the plates, when

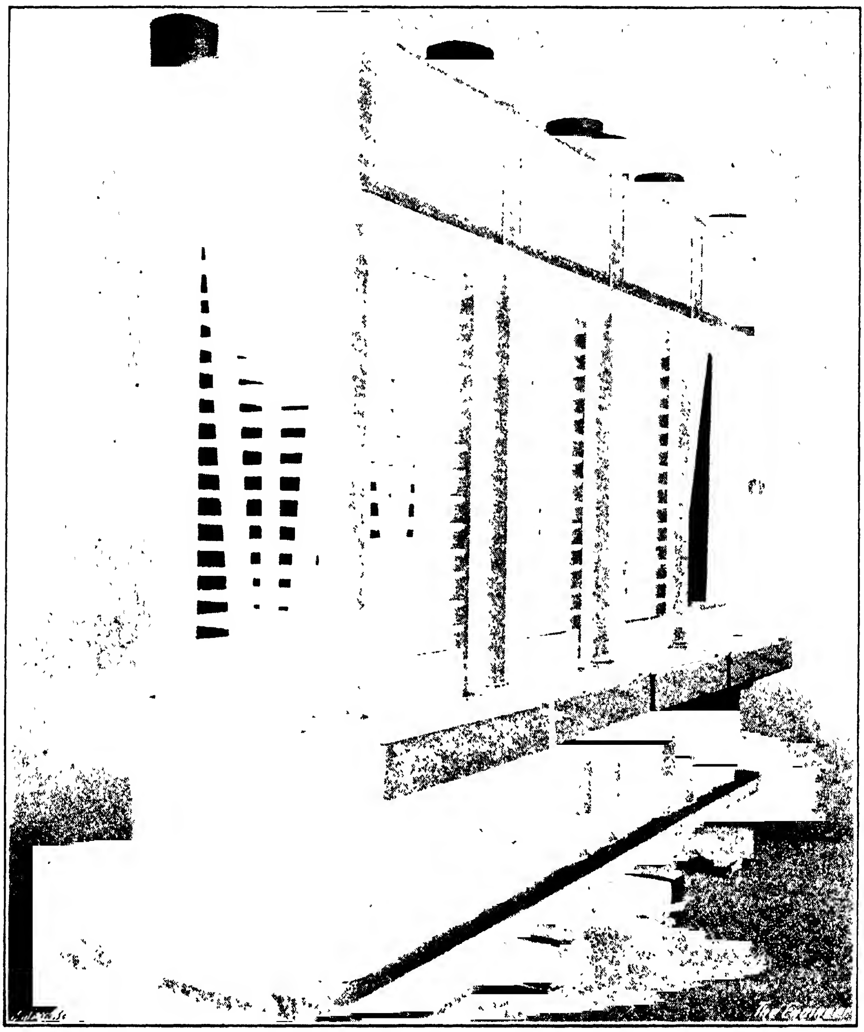


FIG. 39.—Battery of Four Anglo-American Presses—Manlove, Alliott.

pressed upwards, should close together without friction, or at least without cumulative frictional resistance. Were this condition seriously departed from there would be a danger of the upper cakes being less thoroughly pressed than the lower.

The press plates are corrugated in the manner shown in the engraving. These corrugations, as well as the longitudinal ridges which are raised on the plate, are intended, as far as possible, to prevent the meal from spreading when the pressure is applied. If a brand mark is required on the finished cake the desired letters, etc., are

raised or sunk on one side of each press plate. The press plates are, in the instance illustrated, of steel. They are frequently rolled to the required formation. Occasionally they are built up from steel plates. When a brand mark is required on them they are commonly made of malleable cast iron. The same presses may not, however, always be used for one class or quality of material. Under these circumstances, to avoid having to change the plates to obtain merely a different brand mark, plates are made in which the brand mark is formed on a removable portion.

The ram of the press illustrated in Plate I. is 16 in. in diameter. The working pressure is 2 tons per square inch, so that the total force exerted is some 400 tons. This gives about ⅝ ton per square inch as the pressure exerted on the meal cake. The hydraulic pressure is sometimes transmitted to the ram cylinder by means of water alone, or of water mixed with glycerine, to prevent the liquid from freezing too readily. Frequently, however, the working fluid preferred is oil, and, if possible, oil of the same nature as that being extracted, the reason being that any leakage of the working fluid from the cylinder into the tray catching the expressed oil is thus rendered harmless in its effect upon the oil being recovered.

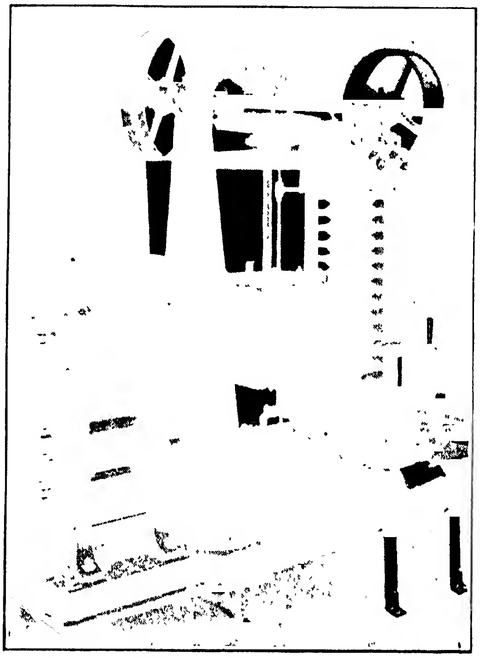


Fig. 40.—Small Anglo-American Press, etc.

Anglo-American presses are usually arranged in oil mills in sets of four, as shown in Fig. 39, where a battery, made by Messrs. Manlove, Alliott, is illustrated. The fourth press in this view is represented without its plates. The presses are entirely separate. Sometimes, however, they are to be found provided with a common gutter or tray for catching the oil. They are worked separately but in unison. Thus, while one press is being charged another is having the pressure applied to it, a third is standing under the pressure, and the fourth is being unloaded. The presses illustrated in Fig. 39 are of the same size and general design as that represented in Plate I. One secondary point of difference is to be noticed in the arrangement made for supporting the plates when the ram is lowered and the press is ready for charging. Instead of the links shown in the drawing, the long edges of the plates are formed with two projecting ears. The gap between these ears is the same on all the plates, and fits on to a vertical flat bar fixed between the top and bottom castings on each side of the press. The breadth of the ears decreases from plate to plate downwards, so that they may pass farther and farther down between a pair of inclined bars similarly fixed, and with steps cut on their facing edges. This " ladder " arrangement, as it is called, has the advantage that it dispenses with the need for any additional means of fixing the position of the plates. No runners are required on the insides of the four columns, for the inclined bars definitely fix the position of the plates crosswise, while the vertical

bars fix their position lengthwise. Instead of solid ears four pins are sometimes to be found on the long edges of the plates fulfilling the same function.

The above examples may be taken as representing the standardised design of Anglo-American presses. This standard design, it may be repeated, uses a ram 16 in. in diameter, and a working pressure of 2 tons per square inch on the ram. It turns out at one pressing sixteen cakes, each weighing from 10 lb. to 12 lb. Various other sizes of press are, however, made, ranging from a twelve-cake to a twenty-cake press. The pressure employed in these presses is in general the standardised 2 tons, and as a rule the diameter of the ram in inches is equal to the number of cakes made at one pressing. For special purposes presses using 3 tons per square inch are made in the larger sizes.

Small Anglo-American Plant.

As a contrast to these regular-sized presses, we illustrate, in Fig. 40, an Anglo-American press, by Messrs. Manlove, Alliott, which is built to a very small scale. The engraving shows a complete self-contained plant, comprising a set of four-high chilled reducing rolls, a heating kettle with steam jacket, meal-moistening arrangement and agitating gear, a meal-moulding machine, and a twelve-cake press, operated by hydraulic power. The plant is capable of dealing with about a ton of seed—containing not more than 35 to 40 per cent. of oil—per day of eleven hours. With the exception of the moulding machine, which is operated by hand, the entire plant is driven from the belt pulley at the right-hand end of the overhead countershaft. The hydraulic power for the press is supplied by a horizontal pump mounted on the press head, and driven from the kettle agitator shaft by means of an excentric and a connecting rod. It will be noticed that the press plates in this example are coupled together by two sets of " lazy tongs." About 8 to 10 b.h.p. is required to drive the whole plant. For treating very oily material similar small-sized plants are made with a press of the cage type. In both forms two presses equivalent in output to the one shown in Fig. 40 are sometimes supplied, so that the whole plant may be run more or less continuously.

Limitations of the Anglo-American System.

The Anglo-American type of press is undoubtedly an efficient piece of machinery, and possesses certain well-marked advantages. Thus, it is comparatively simple and straightforward in design. Running in conjunction with a modern meal-moulding machine it is easily and quickly loaded. It is equally easily unloaded after the meal has been pressed, although in this connection it is to be remarked that the stripping of the press bagging from the cakes taken from the press may involve considerable labour, so much so that in some mills it has been thought advisable to install special machines which permit the stripping to be performed mechanically instead of by hand.

At the same time the general design of this type of press is not altogether free from disadvantages. One obvious drawback lies in the fact that the cake of meal is pressed only on its two faces and not simultaneously round its edges. This defect is partially compensated for by corrugating the press plates in the manner we have explained, so as to prevent or reduce the tendency of the meal to spread. This expedient is more successful with some materials than with others. Thus, if the material being crushed is castor seed, copra, palm kernels, or such like substances of a very oily nature, the mobility of the material, arising from its high oil content, commonly results in the meal spreading excessively, however the press plates may be shaped. If the spreading is excessive, more oil will be left in the cake than is desirable

or profitable, so that the cakes will probably have to be again reduced to meal, and pressed a second time. Second expression oil does not, however, command as high a price as first expression oil. Consequently, as a general rule, it is the oil seed crusher's endeavour to extract as much oil as possible at the first expression.

A second disadvantage of the Anglo-American system of press is, like the first, of importance only when very oily material is being handled. In forming such material into rough cakes in the moulding machine it is difficult to carry the compression as far as it should go without expressing some of the oil from the meal. If this undesirable expression of oil is to be avoided, the rough cakes put into the main press must be less compressed, and consequently thicker than usual. As a result the press has to be made taller by a corresponding amount, and the movement of the ram has to be increased in order to make good the deficiency in the preliminary compression of the meal. Under the high hydraulic pressures in use the latter item reacts unfavourably on the upkeep charges of the press generally, and of the ram and valves in particular, and, in addition, increases the amount of pressure fluid used at each movement of the ram.

It will be gathered from these remarks that the Anglo-American type of press is best adapted for dealing with seed, etc., containing a moderate amount of oil. For very oily seeds a press is required which, in the first place, supports the layer of meal round its edges while pressure is being applied to its faces, so that the meal may be evenly pressed and prevented from spreading, and which, in the second place, will be able to work without the assistance of a separate preliminary moulding machine. Such an appliance is the box cage type of press, which, in several different forms, has recently come into extensive employment, following upon a great increase in the amount of very oily seed, etc., received for treatment. In our next chapter we will illustrate and describe typical examples of cage presses. For the present we need only say that the cage type of press is itself not wholly free from disadvantages peculiar to its design.

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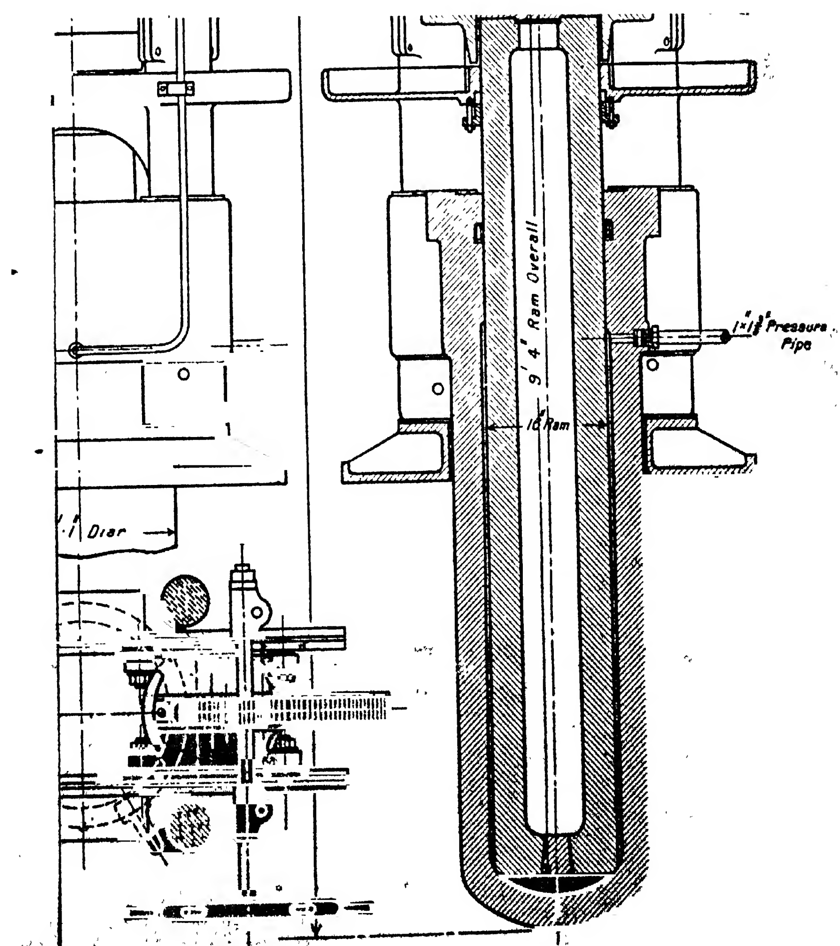

ection Plan Y.Y.

number of ferrules which, fitting between the rings, hold these at the proper distance apart. Surrounding the bars and rings there is a cylindrical lagging of sheet steel united to the top and bottom castings of the cage. This lagging prevents the expressed

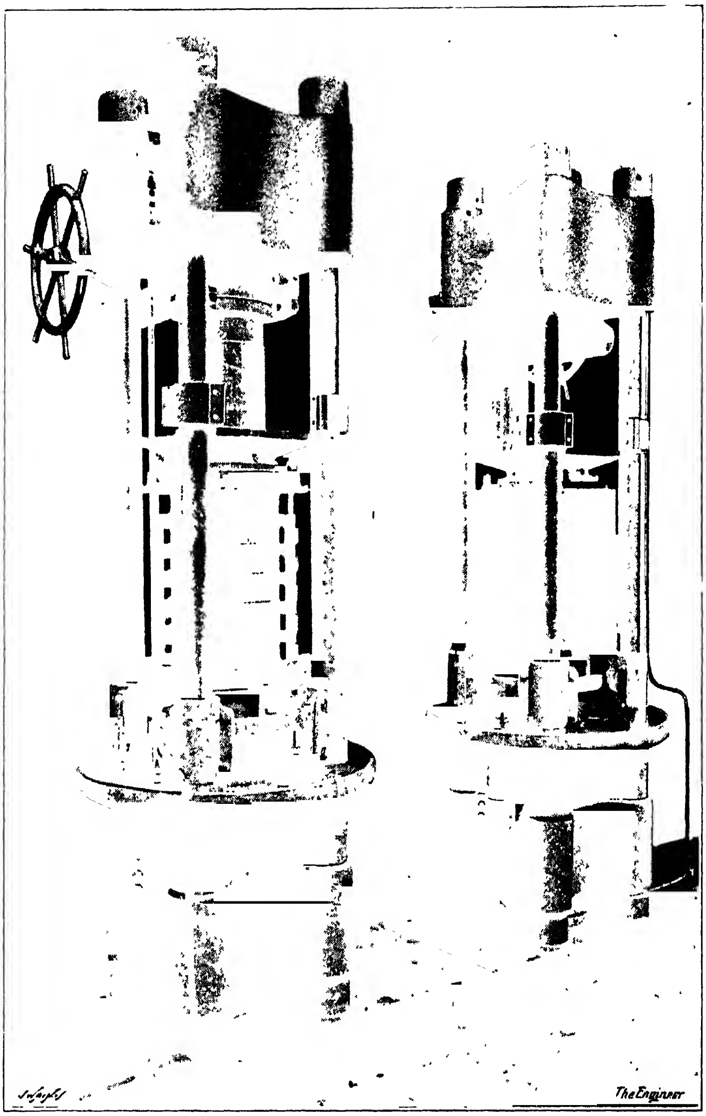

Fig. 41.—Two Small Cage Presses—Manlove, Alliott.

oil from splashing and helps to guide it into the collecting tray below. In Fig. 41 we give a view of two small cage presses made by Messrs. Manlove, Alliott. This engraving helps to make clear the construction of the cage.

The diameter of the cage is equal to that of the ram, which is 16 in., just as it was in the case of the Anglo-American press described in the preceding chapter.

The pressure in the present instance is 3 tons per square inch as compared with 2 tons employed in the cylinder of the Anglo-American press. This full pressure acts on the meal, whereas in the Anglo-American press the pressure on the cakes is much less than the pressure in the cylinder. The pressure, in fact, is, as we stated, but $\frac{2}{3}$ ton per square inch, whereas in the cage press illustrated in Plate II. it is 3 tons per square inch. The employment of such a high pressure as this on the meal in an Anglo-American press would be next to impossible, for it would cause even the least oily of meal to spread excessively between the plates. Its adoption in the cage press has only been made possible by reason of the care and thought which have been given

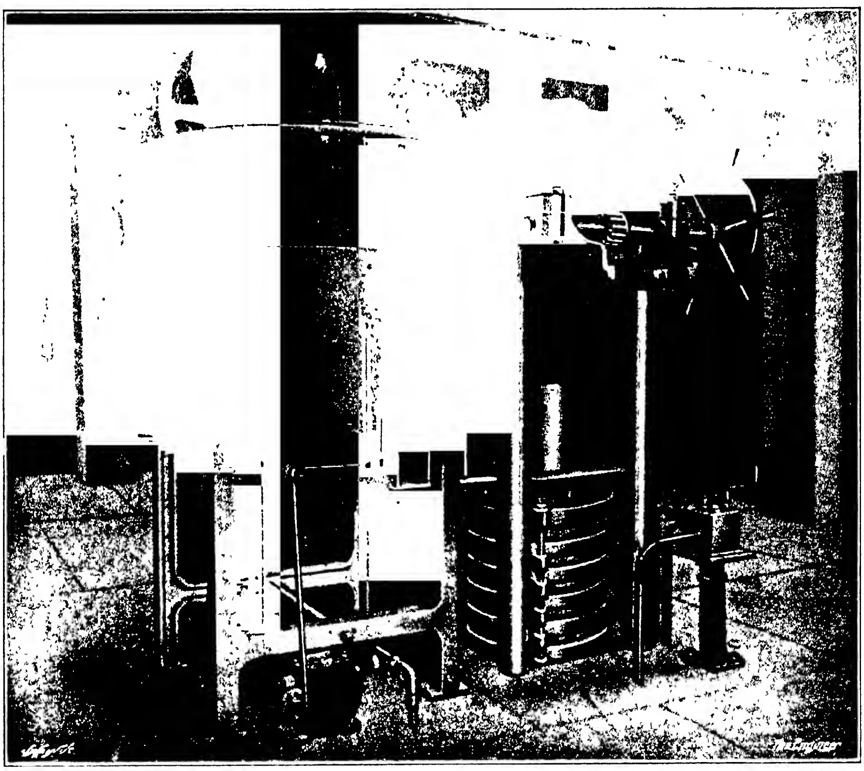

FIG. 42.– Cage Press and Kettle in a Mill.

to the construction of the cage. It may be taken that the outward pressure on the bars of the cage is practically 3 tons per square inch, for the meal during the pressing acts almost like a liquid forced out of a cylinder through a restricted orifice. Under these conditions the greatest care is necessary in designing the cage to ensure that the bars shall not twist or bend and that the spaces between them shall remain constant. How this is secured we have explained. We need only add that the cages of similar presses made by other firms are constructed on the same principle.

Immediately above the cage, as shown in the sectional elevation in Plate II., a cylindrical cast-iron head is slung from the underside of the top casting of the press. This head is mounted on a four-wheeled carriage which runs on a pair of fixed rails. The movement of the head is effected by means of a hand wheel and pinion engaging with a rack on the head. The rack is sunk into the top of the head so that a plain

bearing surface may be provided between the head and the underside of the top casting. Four square-headed studs fixed to the rails form stops which limit the movement of the head. By these means the head can be brought directly over the cage when everything is ready for pressing, or removed to one side to facilitate the loading or unloading of the cage before or after pressing.

Method of Working of a Cage Press.

In Fig. 42 we give a view of a press of the type shown in Plate II. as actually arranged in an oil mill. It will be noticed that the press is disposed about half above and half below the working floor level, and that a heating kettle is placed close beside it. When the cage is resting on its bottom stops the top surface of its upper casting is level with the surface of the plate, hung beneath the kettle, on which the strickling box slides. With the movable press head run back out of the way the strickling box with a charge of meal can thus be pulled over to discharge its contents into the cage. Before this is done, however, a circular steel plate is dropped into the mouth of the cage so that it may come to rest, a short distance down, on four catches projecting through the walls of the top casting of the cage. A circular sheet of press bagging is placed on top of the plate. Thereafter the meal is strickled in a layer into the cage mouth. The plate catches are mounted on a ring so that they may be withdrawn simultaneously to allow the plate, bagging and layer of meal to drop down on to the head of the ram. The fall allowed is not great, however, for the ram to begin with is run up almost to the top of the cage, and as the loading proceeds is allowed to descend slowly to keep pace with the formation of the layers of meal.

The layers thus formed differ from the cakes placed between the plates of an Anglo-American press in the fact that the meal is quite uncompressed. To take full advantage of the capacity of the cage, therefore, strickling is continued until the ram reaches the bottom of its stroke. In this condition about half the depth of the bottom casting of the cage is filled with meal. When pressing commences this meal is at an early stage forced upwards into the cage proper and there, partially at least, makes good the reduction of volume suffered by the general body of the meal.

When the cage is fully charged the movable head is run back over it. The end of the head is turned to a good fit with the bore of the cage. Just before pressure is applied to the meal by the ram, pressure is admitted to two auxiliary ram cylinders—see A, Fig. 41—which, acting beneath the lower casting of the cage, lift the cage a short distance upward so as to cause its mouth to pass on to the cylindrical head and so close the joint. Pressure is then admitted to the main cylinder. As the expression of the oil proceeds the cakes of meal become bound tightly against the walls of the cage. The friction thus developed round their edges is sufficient to lift the cage still further on to the head as the compression of the meal increases. In other words, no provision is made to bring the cage as it rises up against a dead stop. This is an important point. Were such a dead stop in existence the friction round the edges of the cake would result in the cakes being subjected to an effective pressure which would decrease from cake to cake upwards. As it is the cage "floats" with the meal, etc., inside it, and the effective pressure is the same on the top and bottom cakes. It is not, however, necessarily the same towards the middle.

When the cakes have stood for a sufficient length of time under pressure, the main ram is set to exhaust until the cage is lowered on to the bottom stops. The auxiliary hydraulic cylinders are arranged to act as buffers for the cage so as to bring it quietly to rest. The movable press head is then run out. In its outmost position it does not clear completely the face of the top casting of the cage, and therefore forms

a stop which will for the time being prevent the cage from rising. Two additional stops are provided for the opposite side of the top casting of the cage. These two stops consist of half caps which can be swung round on the pillars of the press. With these three stops in action, pressure is once more admitted to the main hydraulic cylinder, so that the ram, rising, may force the cakes out of the cage. To facilitate the ejection of the cakes the bore of the cage is slightly tapered, so that its diameter at the top end is a small fraction greater than at the lower end. Thus a slight upward movement of the cakes, etc., in the cage is sufficient to relieve the binding pressure round their edges.

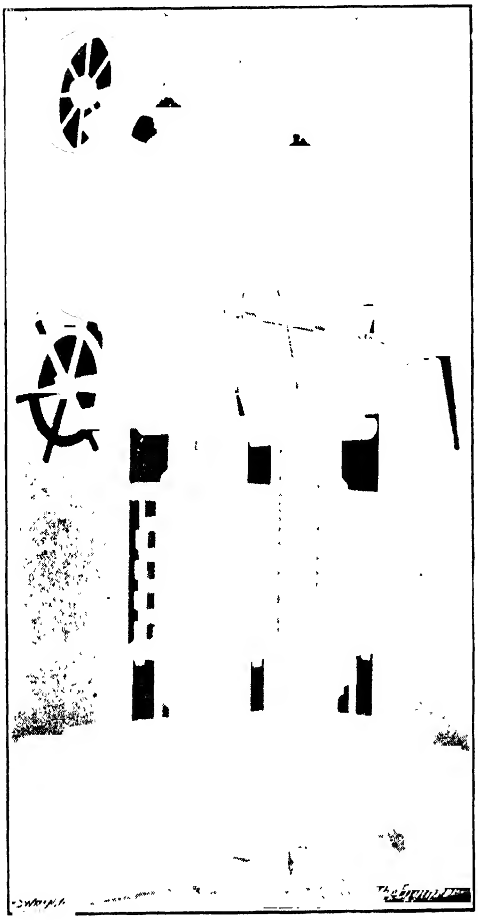

FIG. 43.—Twin Cage Presses—Craig.

In general the cakes produced in a press of this type are again reduced to meal which, after being heated, is expressed a second time. A cage press can be used for this second expression, but as the material has now had the bulk of its oil removed, it can quite conveniently be treated in an Anglo-American press.

ALTERNATIVE CAGE PRESS ARRANGEMENTS.

The press just described is—as shown in Fig. 42—arranged to work by itself in conjunction with a separate meal-heating kettle. Very frequently, however, cage presses are worked in pairs or in sets of three, the two or the three presses in each set being quite independent, except in so far as they are fed from a common kettle. In Fig. 43 we give a view of a two-press set, made by A. F. Craig & Co., Ltd., of Paisley. The general arrangement of this set is shown in Fig. 44. This engraving incidentally indicates the nature of the foundations required for an oil press. The presses, except for one or two obvious minor differences, are similar in design to that already described. The method of charging the cages is, however, quite different. A heating kettle is arranged over the presses, being supported partially on the press heads and partially on an extra pillar. The bottom of the kettle is provided with two outlet holes which register with a hole formed at the centre of each press head—see Fig. 44. Each outlet is controlled by a pair of shutters, one above and one below the press head. These two shutters are connected so as to be operated simultaneously. Thus a double movement of the control handle fills the hole in the press head with meal and then discharges this measured quantity into the cage.

An alternative arrangement by Manlove, Alliott & Co., Ltd., is indicated in

Fig. 45. This arrangement is particularly suitable where large presses are required. It consists of a battery of four presses, a separate compressor and extractor press and a power-driven travelling carriage. The compressor and extractor press is provided with a movable head, as in the case of the presses described above, so that its cage

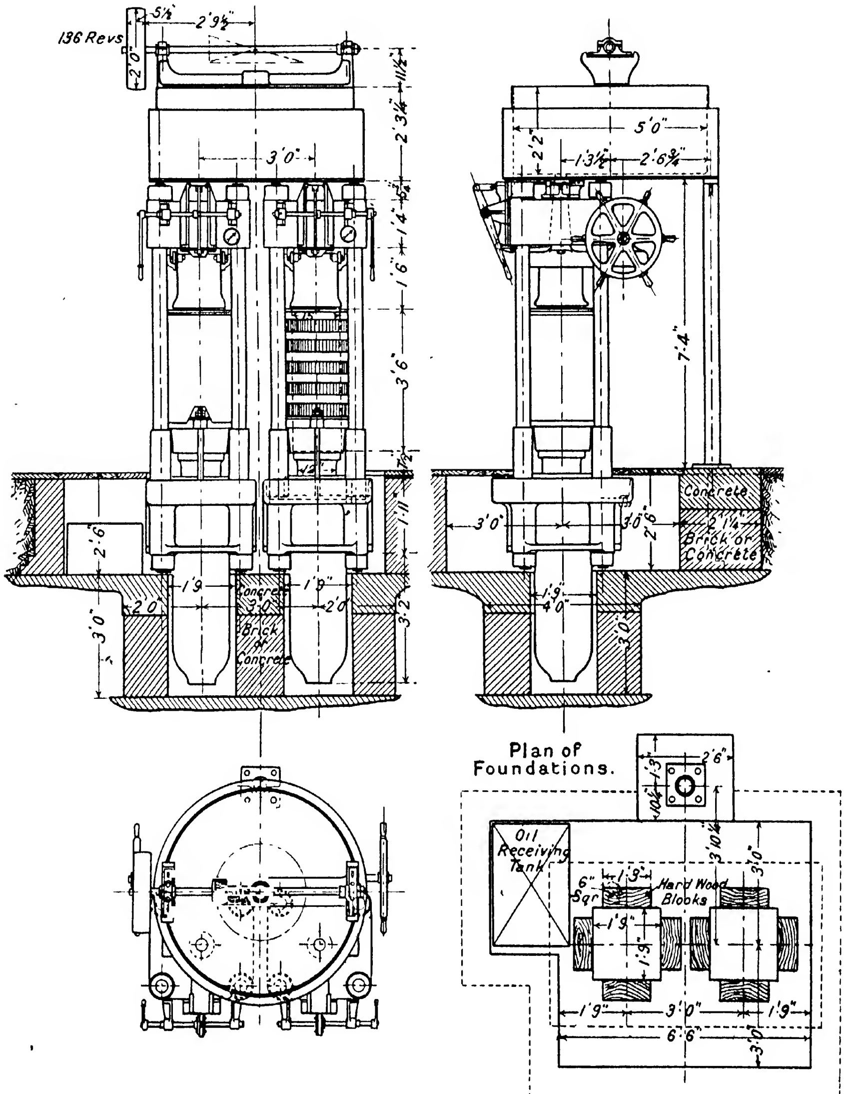

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FIG. 44.—Twin Cage Presses—Craig.

may readily be charged with layers of meal from the adjacent kettle. The cage may be regarded as being in two parts, the lower of which is fixed, in so far, at least, as the position of its centre line is concerned, while the upper part can be run out on to cross rails on the top of the travelling carriage. The strickling proceeds until both parts are filled with layers of meal. Pressure is then applied in the ram cylinder so as to com-

press all the meal into the upper movable part of the cage. When this is accomplished the pressure is released, and the movable part of the cage is run out on to the travelling carriage, which then transports it to one of the four main presses. The travelling carriage is provided with two sets of cross rails so that it may support a cage ready for pressing, while giving accommodation for the reception of a cage the pressing of which has been completed. On the return journey, therefore, the carriage brings back to the preliminary press a cage from which the cakes are ready to be extracted. This extraction is performed at the preliminary press in the manner indicated already for the single press by the same makers.

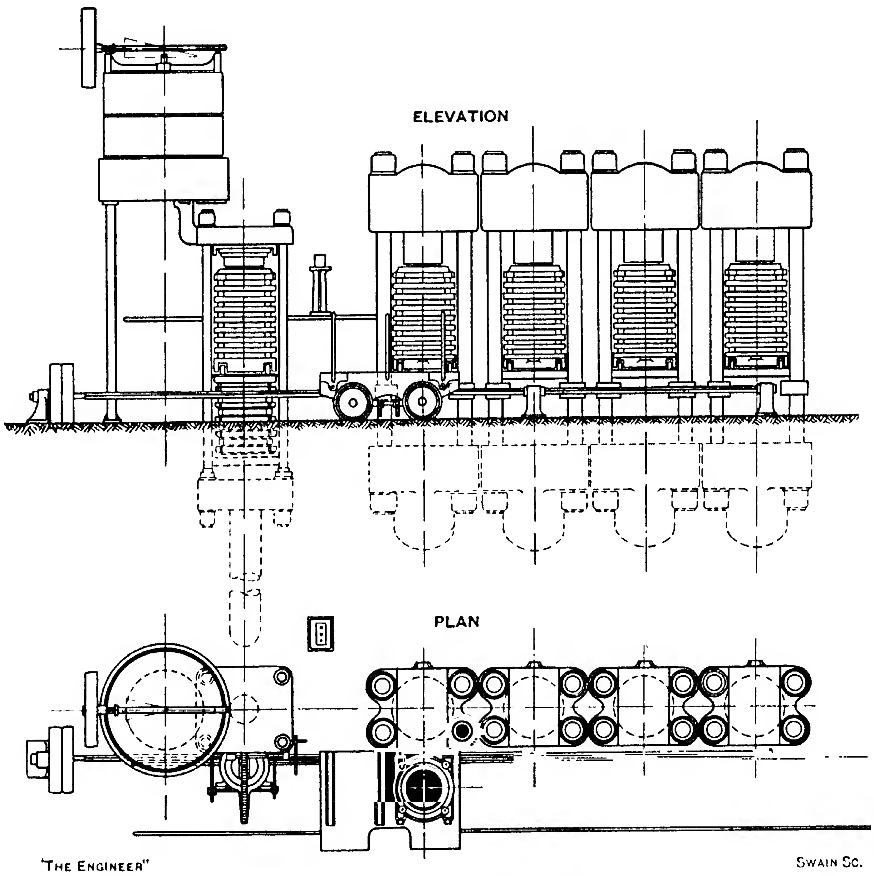


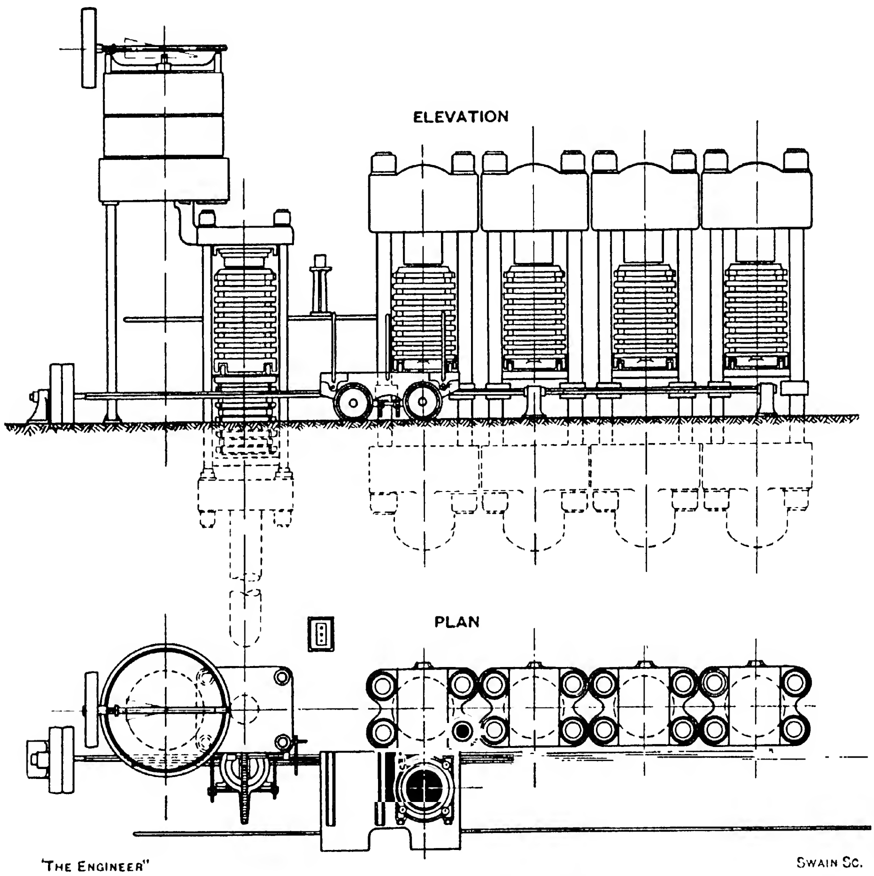
FIG. 45.—Battery of Four Cage Presses—Manlove, Alliott.

The preliminary press used in this system of working is, we think, to be regarded properly as the equivalent of the moulding machine required with an Anglo-American type of press. Its adoption has the distinct advantage that the main presses can be made with fixed, and not sliding heads. Further, it will be gathered that as the "slack" in the meal is taken up in the preliminary press, the movement, and therefore the length, of the rams in the main presses can be made quite short.

REVOLVING CAGE PRESS.

Another interesting and important alternative arrangement of working cage presses in groups lies in the adoption of a rotary principle. An example of the applica-

press all the meal into the upper movable part of the cage. When this is accomplished the pressure is released, and the movable part of the cage is run out on to the travelling carriage, which then transports it to one of the four main presses. The travelling carriage is provided with two sets of cross rails so that it may support a cage ready for pressing, while giving accommodation for the reception of a cage the pressing of which has been completed. On the return journey, therefore, the carriage brings back to the preliminary press a cage from which the cakes are ready to be extracted. This extraction is performed at the preliminary press in the manner indicated already for the single press by the same makers.



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Revolving Cage Press.

Another interesting and important alternative arrangement of working cage presses in groups lies in the adoption of a rotary principle. An example of the applica-

tion of this principle is illustrated in Plate III., where we show a revolving cage press made by A. F. Craig & Co., Ltd., of Paisley, under Craig and Morfitt's patent. A photograph of such a press is reproduced in Fig. 46.

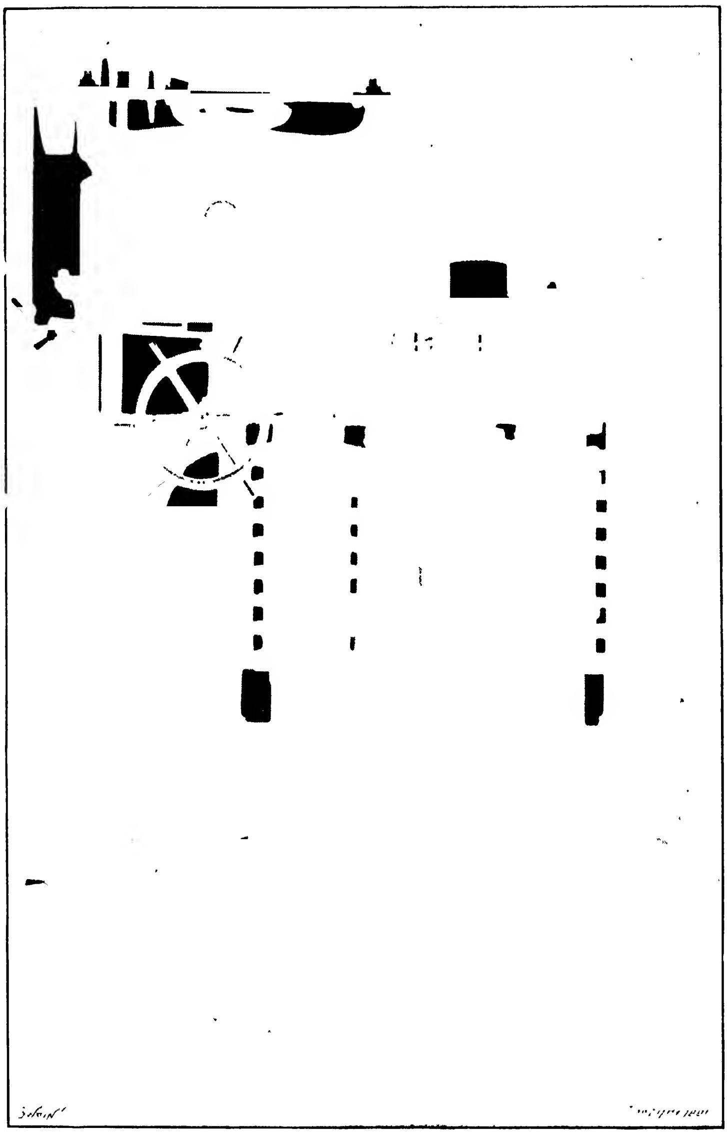


Fig. 46. Revolving Cage Press (Craig).

The fundamental feature of the design lies in the provision of three cages arranged with their centres at the apices of an equilateral triangle, the whole being rotatable as a block round an axis passing through the centre of the triangle. Corresponding to the three cages there are three fixed press heads and three hydraulic cylinders and rams, arranged with their centres at the apices of an identical equilateral triangle.

During a complete rotation of the cages about their common axis each cage passes in turn between each press head and its corresponding hydraulic ram. The method of working is to fill cage A—see Plate III.—with meal from an adjacent kettle, while it stands beneath one of the press heads, and to give the meal in it at this point a preliminary compression. The cage system is then rotated clockwise through 120 degrees, so as to bring cage A beneath the second press head where the meal is subjected to an intermediate compression, and so as to bring cage C into the position formerly occupied by cage A. Cage A is allowed to stand under pressure while cage C is being emptied and recharged with meal. Thereafter a further rotation of the cage system through 120 degrees brings cage A beneath the third press head where its meal receives the final compression. Meanwhile, cage C is receiving its intermediate compression beneath the second press head, while cage B beneath the first press head is being emptied and recharged. A final rotation of the cage system brings cage A back again beneath the first press head for emptying and recharging. The meal, it will be seen, is pressed in three separate stages. It will also be gathered that the arrangement secures practically continuous working. It is stated that everything about a set of these presses can be worked by one unskilled man with the assistance of a boy.

The detailed design of the press is noteworthy. The meal-heating kettle is of the usual type, and is fitted with the usual means of stirring, heating and moistening the meal. It is supported partly on the first press head and partly on two separate columns. The strickling box slides on a surface with guiding edges formed on top of the first press head. A circular hole equal in diameter to the bore of the cage is formed in the press head, and is provided with four catches, operated simultaneously, for temporarily supporting the usual steel disc and circular piece of press cloth on to which the meal is deposited from the strickling box. The withdrawal of the catches allows the plate, cloth, and layer of meal to fall on to the ram head. During the charging operations, the ram starting from its highest position is allowed slowly to fall. Charging is continued until not only the cage, but the compression chamber—D in Plate III.—beneath it is completely filled. When this stage is reached, a run-out slide, operated by racks, pinions and hand wheel, is moved back to close the opening in the press head from the underside. This slide is provided with a shallow circular boss turned to fit the bore of the cage.

When matters are in this condition, two auxiliary hydraulic rams are brought into action beneath the compression chamber which, lifting this chamber and the cage, close the joint between these two parts and also the joint between the cage and the run-out slide beneath the press head. Pressure is then applied beneath the main ram which, rising through the compression box, compresses the meal entirely into the cage. A certain amount of oil is forced out of the meal at this stage, and is caught in a tray beneath the press. Even before the meal is entirely pushed out of the compression box, the pressure may be sufficient with some seeds to express a portion of the oil from the meal. For this reason the top end of the compression chamber is finely perforated, so that the oil expressed may escape readily. When the pressure of the main ram is relieved, the meal layers tend to expand a little. To obviate any trouble which this expansion might cause when it comes to rotating the cages, the meal is compressed further into the cages than would be necessary were expansion absent.

The compression suffered by the meal in the preliminary press is sufficient to bind the bulk of it within the cage, so that when the ram falls it remains there. The steel plate and the press cloth at the foot of the cage and one or two of the lowest layers of meal require, however, to be supported when the ram is lowered and while

the cage is being turned round to come beneath the second and third press heads. This support is given by a pair of spring catches arranged in the lower end casting of the cage. These catches slip in beneath the lowest press plate as the ram falls. They are automatically pushed back by the second and third rams when these rise into the cage and fall into action again when these rams are lowered. Means have to be provided at the preliminary press, whereby these catches may, while the press is being charged, be rendered inoperative, so that they shall not prevent the charge from passing down into the compression chamber. These means consist of links and levers operated from the long handle F shown in Plate III.

The manner in which the cages are mounted requires a word of explanation. They have to be free to revolve together about their common axis, and at the same time have to be free to rise vertically a short distance under the action of the auxiliary hydraulic rams, so that the joints between them and the press heads may be closed before the main ram is brought into action. The support for the cages consists primarily of a central vertical hollow cylindrical casting—G in Plate III.—within which are disposed the inner columns carrying the stationary press heads. This cylindrical casting is supported at its bottom flange on a series of rollers journalled in a casting fixed on top of the lower—stationary—castings of the three presses. The position of its axis is fixed by means of three horizontal rollers journalled on the fixed roller casting and bearing against the interior of the cylindrical casting—see the plan view in Plate III.

The top flange of the cylindrical casting is splayed out into the form of a six-armed spider. A little more than half-way down a similar set of six arms projects from the casting. The cages are situated between alternate pairs of these arms and are united thereto by means of rods running between the top and bottom cage end castings and passing through eyes in the ends of the arms. The cages are thus free to rise vertically, but are compelled to rotate solidly with the central cylindrical casting.

From the spider arms six brackets—not shown in Fig. 46, but clearly indicated in Plate III.—depend and support, crinoline-wise, a circular rack which encloses all three cages at the level of their bottom castings. This ring passes close to, but within the outer columns supporting the press heads, and is provided with additional carrying means in the shape of three rollers mounted on the bottom castings of the presses and bearing against its underside. The ring meshes with a pinion on a vertical shaft provided with a hand wheel. By turning this hand wheel the ring, central casting and cages are rotated as one body from one setting to the next.

In the press illustrated in Plate III., the cages are 19 in. in diameter and 54 in. long. The extension chamber at the preliminary press is 42 in. long. These dimensions give the press a capacity of about 20 cwt. of copra per hour. The diameters of the lower ends of the first and second rams are less than the diameter of the cage. Consequently, the preliminary and intermediate pressures on the meal are less than the pressure admitted to the hydraulic cylinders. The lower end of the third ram is of greater diameter than the cage. so that the final pressure on the meal is greater than the hydraulic pressure in use. With a hydraulic pressure of 2 tons per square inch, the pressures on the meal work out at the following values : Preliminary press, 11 cwt. ; intermediate press, 30 cwt. ; final press, 60 cwt. per square inch. A high final pressure is thus obtained without employing an equally high hydraulic pressure. This is of importance, because at a pressure of 3 tons per square inch the wear and tear on the pumps and valves of the hydraulic pressure supply system is apt to become a serious item in the upkeep charges.

A schedule of working times for this press has been supplied to us by the makers.

According to this, eight minutes are allowed for emptying and filling the cage at the preliminary press. It is allowed to stand under pressure for seven minutes at this press. One half minute is consumed in lowering the rams—all three rams are lowered simultaneously—and another half minute is required to change the positions of the cages. Thus the meal is under pressure for seven minutes in the preliminary press, fifteen minutes in the intermediate and fifteen minutes in the final, or altogether, thirty-seven minutes out of a total working time of forty-eight minutes.

Other Arrangements of Cage Presses.

Various other forms of cage presses are made. We can, however, but briefly mention two, both made by Robert Middleton & Co., of Leeds. One of these, Lambert's patented " continuous " oil press, is of the revolving type, but instead of having three cages, as in Messrs. Craig's press described above, it has but two, one for the preliminary, and the other for the final, pressing of the meal. The meal is fed into the preliminary press at the foot instead of at the top of the cage by means of a pair of circular steel boxes mounted on a table which rotates about one of the press columns in such a way that while one box is beneath the preliminary press, the other is beneath the kettle receiving a charge of meal. In another arrangement by the same makers, the kettle works in conjunction with a preliminary press much in the way illustrated in Fig. 45. Instead, however, of the main presses being arranged in a row, they are in this case arranged on the arc of a circle. The cages are transported, when filled, from the preliminary press to the main presses on a turntable provided with rails and hydraulic running-out gear.

The chief objection which can be urged against the cage type of oil-press is that its construction, compared with the Anglo-American type, is complicated. Its successful working depends very largely on the care given to the design and construction of the cage This, as may be supposed, is an expensive item. Efforts, therefore, have been made to cheapen the cost of manufacture, while retaining the principle of the cage press by substituting for the cage built up of vertical bars, a cylindrical box of very finely perforated sheet steel.

CHAPTER X

THE GENERAL ARRANGEMENT OF OIL MILLS

HAVING described in the two preceding chapters the construction and working of typical modern oil presses, it is desirable that we should now briefly deal with the general arrangement of oil mills and with some of the machines and appliances which,

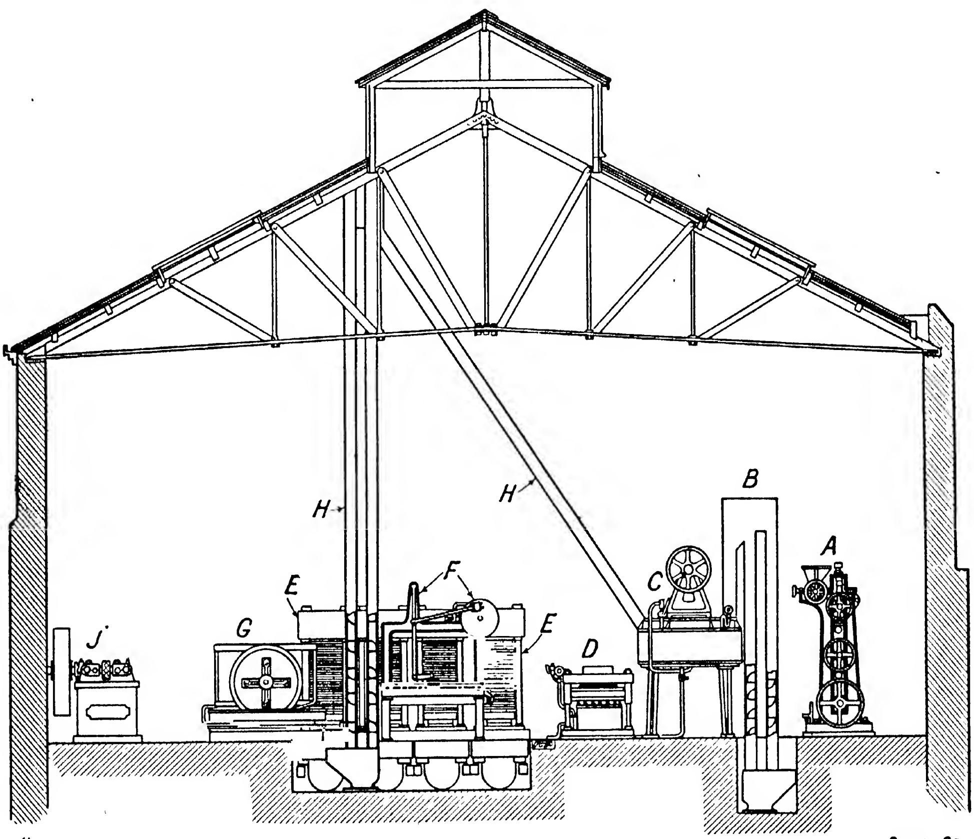


FIG. 47.—Cross Section of a Mill with Anglo-American Presses—Rose, Downs & Thompson.

in addition to the rolls, kettles, moulding machines, and so on. already described, are commonly to be found installed therein.

ANGLO-AMERICAN OIL MILL.

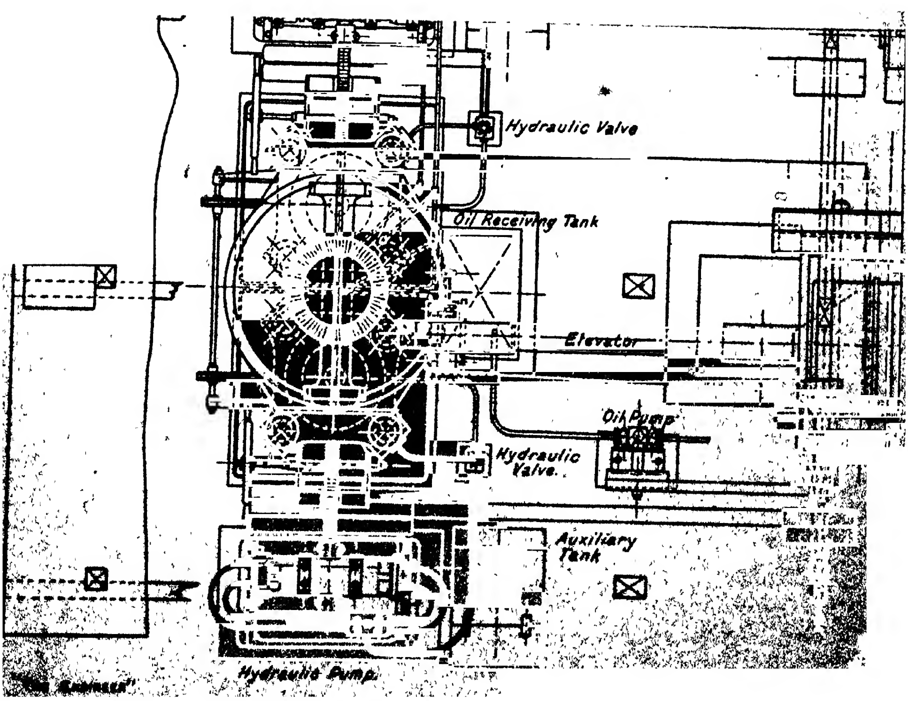
In Fig. 47 we give a cross-sectional elevation of a typical oil mill arrangement as carried out by Rose, Downs, & Thompson, Ltd., of Hull. The plant shown can treat per hour 15 to 18 cwt. of linseed or similar small seed requiring only one pressing.

At A is shown a set of 5-high crushing rolls of standard design. The individual rolls are 3 ft. 6 in. long, and have an average diameter of about 16 in. The general design is similar to that of the examples illustrated and described in a previous chapter. From these rolls the crushed seed is conveyed by a small chain bucket elevator B into the meal-heating kettle C. The kettle follows the usual design, and is 5 ft. in internal diameter by 2 ft. 2 in. deep. It is lagged with hair felt and is provided with a steam reducing valve and a steam trap for the exit of condensed water. The moulding machine D receives the hot meal from the kettle in the manner we have already described, and reduces each charge of meal from an unconsolidated layer 3 in. thick to a rough-formed cake 1¼ in. thick. The four presses E are of the standard Anglo-American design and size. Each is capable of making at a charge sixteen cakes, measuring about 28 in. by 12 in. and weighing 10 to 11 lb. each. The press rams are 16 in. in diameter and work under a pressure of 2 tons per square inch. The presses stand in a steel tank sunk into the floor. The expressed oil is caught in this tank and is drawn thence by an oil pump and forced into storage vessels. These vessels have a capacity of 50 tons, and are provided with oil taps and with additional taps whence may be drawn any mucilage which may settle out from the oil on standing.

The cakes taken from the press are stripped of their bagging, and one by one are placed on the table of a power-driven paring machine F. With these machines we will deal presently. Their function is to pare off the extra oily edges of the cakes so as to trim the cakes to a more or less uniform size, and further, to recover the oily edge portions for additional treatment. The parings are passed into an edge runner G where they are reduced again to the form of meal. This meal is then returned by means of the elevator H to the kettle C, where it is mixed with a fresh charge. The edge stones are of Derbyshire grit 4 ft. in diameter by 12 in. thick. Besides reducing the parings to the form of meal, they are also used to treat likewise any broken or damaged cakes arising from the working of the presses.

Hydraulic pressure is supplied to the presses by a set of horizontal belt-driven pumps J. No accumulators are used. The base of these pumps forms a cistern, whence the pumps draw their supply of pressure fluid—oil usually—and to which the exhaust from the presses is delivered. In working oil presses there are two distinct periods: During the first the meal and press bagging are closing up. The resistance experienced by the press ram is an increasing quantity, and the movement of the ram is considerable. During the second period the meal is left standing under pressure. The resistance on the ram is now constant, and its movement is practically zero. It is distinctly economical to use a low pressure on the ram during the first period, followed by a higher pressure during the second. In addition, it is found desirable to use a low pressure during the earlier period, because if a high pressure is used the chances of the meal spreading are increased and the press bagging is likely to be quickly damaged. These considerations are also of importance at the moment when the change over from low to high pressure is being made. The change should not be made suddenly; the pressure, rather, should grow gradually to its maximum value. This is secured usually by employing regulating valves of a suitable type. The pumps in the installation illustrated in Fig. 47 have two low-pressure barrels 3 in. in diameter and two high-pressure barrels 1¼ in. in diameter.

The whole plant is driven by a single-cylinder horizontal engine of 45 i.h.p. running at 100 revolutions per minute. The steam supply is obtained from a Lancashire boiler 20 ft. long by 6 ft. diameter. This is more than large enough to meet the demands of the engine. It has, of course, in addition to supply steam for the heating kettle and to the moulding machine. The latter, in the absence of a low-pressure


Hydraulic Valve
Oil Receiving Tank
Elevator
Oil Pump
Hydraulic Valve.
Auxiliary Tank
Hydraulic Pump
"The Engineer"

accumulator, has to be of the steam-operated type. The whole plant illustrated occupies a room measuring 34 ft. by 28 ft. by 18 ft. high, and engages per shift the attention of three men, not counting the boiler and engine attendant.

Cage and Anglo-American Presses in Combination.

The ground plan of a mill—also by Rose, Downs & Thompson—for treating seeds which require to be pressed twice, is shown in Fig. 48. The seed received at A is passed through a set of rolls B and is conveyed by an elevator C to a kettle D. If the first pressing is to be carried out cold no steam is admitted to the jackets of this kettle. The meal, hot or cold, is distributed from it into two cage presses E, E beneath it. The round cakes left after the first pressing are broken up in a cake breaker F,

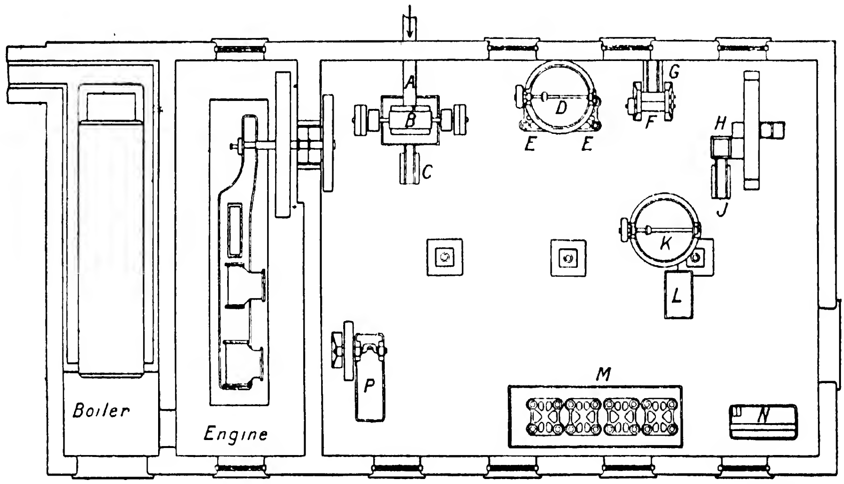


Fig. 48.—Plan of Mill with Cage and Anglo-American Presses—Rose, Downs & Thompson.

and are taken by an elevator G to a disintegrator H, where the pieces are reduced to meal again. An elevator J then conducts the meal to a second kettle K and a moulding machine L. The second pressing is conducted in a set of four Anglo-American presses M. The paring machine is shown at N and the hydraulic pumps at P.

The oil mill arrangements represented in Figs. 47 and 48 may be regarded either as complete in themselves or as units of larger mills.

Cage Press Oil Mill.

In Plate IV. we reproduce the general arrangement drawing of an oil mill equipped with cage presses, all the machinery for which was supplied by A. F. Craig & Co., Ltd., of Paisley. The mill as here shown was specially designed for treating copra, but by suitably varying the preparatory crushing portion of the plant it can be used for treating any kind of seed or nut. Its designed capacity is 10 cwt. of copra per hour if one pressing only is given to the material, and 8½ to 9 cwt. if it has to be pressed twice. The cage presses, two in number, are fed with hot meal from an overhead kettle, the arrangement being in general on the lines of the pair of presses by Messrs. Craig, illustrated in Fig. 44 of our preceding chapter. Each cage is 19 in.

in internal diameter by 100 in. long. The rams are 18½ in. in diameter and work under a pressure of 2 tons per square inch.

The material is first passed through a set of reducing rolls 18 in. wide. From these it is raised by an elevator and dropped into the hopper of a set of shredding and crushing rolls. 36 in. wide, of the type illustrated in Fig. 4 of our third chapter. A second elevator then lifts the material to the meal kettle at the top of the presses. The expressed oil collects in a receiving tank and is thence forced by an oil pump,

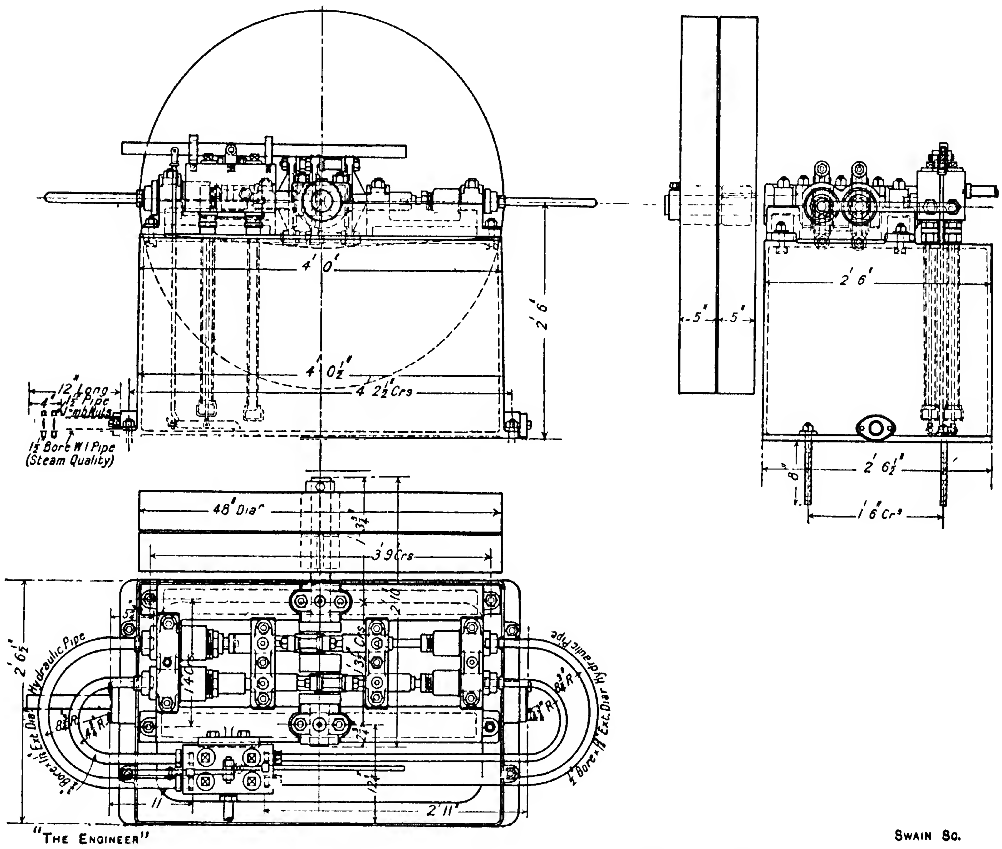


Fig. 49.—High and Low-Pressure Oil Press Pump—Craig.

with a ram 3 in. in diameter by 3 in. stroke, into a storage vessel. The whole plant is driven by a 50 b.h.p., single-cylinder, horizontal engine supplied with steam at 100 lb. pressure by an 18-ft. Cornish boiler. The labour required to operate the plant consists of two men for the presses and a man or a boy to attend to the reducing and crushing rolls. A second shift, similar to the above, is required for night working, as the plant is, as usual, run continuously. In addition to these, two men are required to look after the oil, the cakes, and the storage of the copra. These men, however, work only during the day shift.

Hydraulic Pumping Equipment.

As in the case of the mill arrangements illustrated in Figs. 47 and 48, the presses represented in Plate IV. are operated directly by pumps without accumulators.

Each press has its own pump, so that it may be worked entirely independently of the other. In Figs. 49 and 50 we give the reproductions of a drawing and a photograph, which will enable the construction of the pumps to be understood. They are of a horizontal, belt-driven type, and are mounted on top of a cast-iron suction tank for the hydraulic fluid. An additional suction tank, it will be noticed from the general arrangement drawing, is also provided for each pump. Each pump has four rams, all of 3 in. stroke. The rams are reciprocated by a crankshaft running at about 60 revolutions per minute, and working within blocks, which can slide vertically in crossheads, to which the rams, suitably guided, are attached. On one side of the crosshead the rams are $2\frac{1}{2}$ in. in diameter, and generate the low pressure required during the early stages of the pressing, as above explained. The two high-pressure rams on the other side of the crosshead are 1 in. in diameter. All four rams draw from the pump cistern through separate pipes extending downwards from the valve box. Their action is united during the earlier stage of the pressing, but when a pressure of 700 lb. is reached in the press cylinder, the low-pressure rams are automatically shut down, while the high-pressure rams continue the work until the final pressure of 2 tons is reached. This effect is obtained by means of a weighted lever mounted on top of the valve box and connected by a rod and lever to a rod passing up each low-pressure suction pipe. The latter rod acts upon the low-pressure suction valves in such a way, than when it rises it throws these valves out of action and causes the delivery from the low-pressure rams to pass back again into the cistern. The rise of the weighted lever when 700 lb. pressure is reached, is brought about by a plunger acting beneath it close to its fulcrum. A second weighted lever on the high-pressure side of the valve box constitutes the working element of a safety valve, which prevents the pressure generated from rising above 2 tons per square inch. The pumps are provided with fast and loose belt pulleys, but during a spell of working they can be allowed to run continuously, their delivery when not actually required at the presses being returned at the press control valves back into the auxiliary suction tanks.

Fig. 50.—Oil Press Pump—Craig.

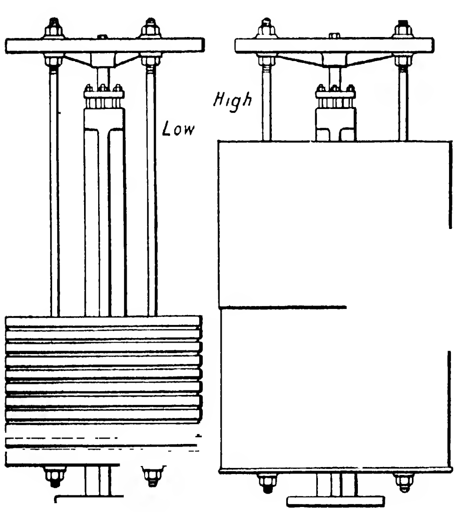


Fig. 51.—Oil Mill Accumulators—Rose, Downs & Thompson.

Accumulators.

The method of working hydraulic oil presses without accumulators, exemplified in the above mill arrangements, entails the use of a separate pump for each press if the presses are to be capable of being operated independently. Naturally, therefore, this method is best suited to the case of oil mills having but few presses. In such cases, little, if anything, is to be gained by adopting accumulators ; indeed, these may well be but an added complication, and entail the provision of more floor space

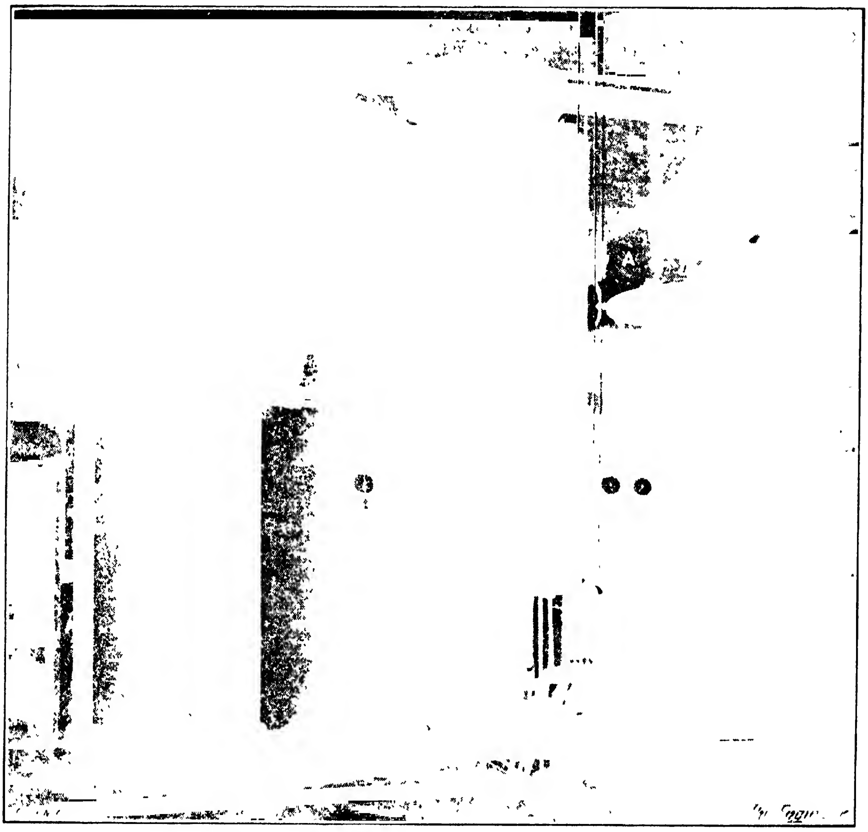


Fig. 52.—Accumulators in an Oil Mill—Manlove, Alliott.

and head room than is strictly economical. When, however, the number of presses in the mill exceeds a certain figure, a point is reached at which both first cost and floor space will be economised by providing accumulators—worked by one or two pumps—rather than separate pumps for each press. Practice implies that this point is in general regarded as having been reached, when there are eight or more presses in the mill.

When accumulators are installed, it is usual to find one arranged for a high-pressure supply working in conjunction with one or more for a low-pressure supply. An additional advantage of using accumulators in large mills lies in the fact that the low-pressure supply can be utilised for working the meal-moulding machines, if the presses are of the Anglo-American type, the hydraulic cake-trimming machines referred to

later on in this chapter, and any hydraulic lifts with which the mill may be equipped. It is frequently stated that a still furthei advantage attending the use of accumulators is to be found in their "safety-valve action," for in general it is impossible to admit to the press cylinder and its connections a pressure greater than that for which the accumulator is deliberately loaded. The implied danger, however, need be no greater with a properly arranged system of independent pumps than it is with accumulators.

The accumulators used in oil mills are in no essential respect different from those used for other purposes. The low-pressure accumulator—see Fig. 51—may be loaded with cast-iron weights, but usually it is loaded similarly to the high-pressure accumulator shown also in Fig. 51, namely, by means of a mild steel plated case filled with slag, sand, or other material. The cylinder is of cast iron, formed externally with two ribs, on which the weight case is guided. The weights are hung from a cast-iron cross-head fixed to the top of the ram. Sometimes matters are reversed, the ram being fixed to the floor and the cylinder, with the weight case attached to it, sliding on the ram.

The low-pressure accumulators are commonly designed for a pressure of 500 lb. to 600 lb. per square inch. Their rams may have a diameter of from 8 in. to 15 in., and a stroke of from 8 ft. to 12 ft. The high-pressure accumulators give a working pressure of 2 or 3 tons per square inch, according as the presses are of the Anglo-American or of the cage type. Their rams vary in diameter from $2\frac{1}{2}$ in. to 5 in., and in stroke from 5 ft. to 12 ft. In Fig. 52 we give a view of three accumulators by Manlove, Alliott & Co., Ltd., as erected in an oil mill. Here there are two low-pressure accumulators, each with a stroke of 10 ft., and one high-pressure accumulator with a stroke of 5 ft.

FIG. 53.—Accumulator Pump—Manlove, Alliott.

ACCUMULATOR PUMPS.

The pumps employed in connection with the accumulators in an oil mill are usually of a vertical reciprocating belt-driven type. An example by Manlove, Alliott & Co., Ltd., is illustrated in Fig. 53. The cast-iron base is in the form of a tank into which the hydraulic fluid from the press exhausts and from which the pump draws its supply. A bridge is cast across the top of the tank, and on this are fixed the side frames carrying the driving shaft. The side frames are fixed to the tank by means of bolts, which extend right from the caps of the driving shaft bearings to the underside of the bridge. The driving shaft carries an excentric at each end. The excentric rods are of cast steel and each reciprocates a crosshead to which two rams are attached. The rams

work within forged steel blocks fitted into the top of the tank. The suction valves and the delivery valves are fitted with renewable seats of nickel steel. The delivery valves are, as shown in the engraving, arranged in two steel blocks so that access may readily be had to them. The chief point of importance to pay attention to in the design of such a pump as this is the accessibility of those parts liable to wear or get out of order. Oil mills usually are run both night and day, so that any repairs required to the machinery have to be effected in the short meal time stoppages.

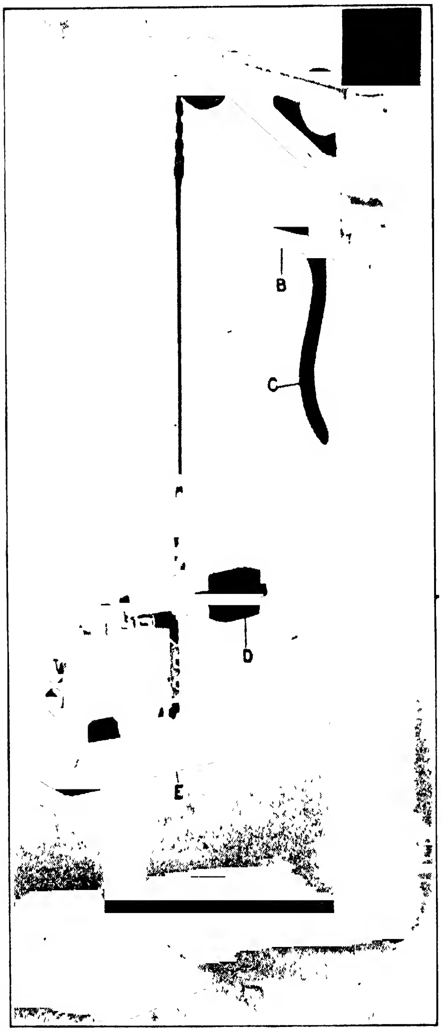


Fig. 54.—Relief Valve Details—Manlove, Alliott.

Accumulator Relief Valves.

As usual, means have to be provided whereby the pumping up of the accumulators is stopped when their rams reach a certain height. Elsewhere this is frequently effected by automatic means which stop the pumps. In oil mills, however, it is customary to keep the pumps running continuously and, when required, to deflect their delivery back through a relief valve into the supply tank. An automatically worked relief valve arrangement by Messrs. Manlove, Alliott is illustrated in Fig. 54. When the weight case of the accumulator reaches its prescribed height, a bar on its crosshead, shown at A in Fig. 52, strikes the end of the lever B (Fig. 54), and pushes it upwards. The opposite end of this lever is connected by a chain, etc., in the manner shown to the weighted lever of the relief valve. This lever is therefore moved up. It is held up by the action of the cam lever C which, moving out under the influence of a spring plunger, engages the pin shown on the side of the lever B. When the accumulator falls again the bar A (Fig. 52) strikes the now projecting cam lever C, moves it in, and allows the weight of the lever D to pull down the lever B and so resets the arrangement. When the lever D is raised the delivery from the pump is deflected from the accumulators back to the supply tank. When the lever falls again the delivery to the accumulators is resumed. The actual raising of the weighted lever is not effected by the chain and rod, but by a plunger beneath it. A by-pass supply of low-pressure fluid is admitted beneath this plunger by a piston valve E operated when the lever B is raised. During the resetting of the arrangement this piston valve acts as a dashpot and prevents the relief valve from being dropped violently on to its seating.

CAKE-TRIMMING MACHINES.

Cake-trimming machines, as will have been gathered from what has already been said, form quite important items in the economy of oil mills. They are made in a variety of forms. A simple arrangement for paring the edges of straight-sided cakes, made by Robert Middleton & Co., is shown in Fig. 55. This machine is attended by two youths and can pare two cakes at a time. It comprises two knives moved by power along the edges of a slot at the centre of its table. The oily parings fall into the slot, where they are caught in a trough and are broken up and moved forward to the spout by a series of steel conveyor knives mounted on a power-driven shaft within the trough. A similar type of machine is made by Rose, Downs & Thompson, Ltd, except that all the driving gear is carried on two standards bolted to the table top, the idea being that in this way the working parts cannot become clogged with oily cake parings. A machine of this type is indicated in the mill arrangement, Fig. 47.

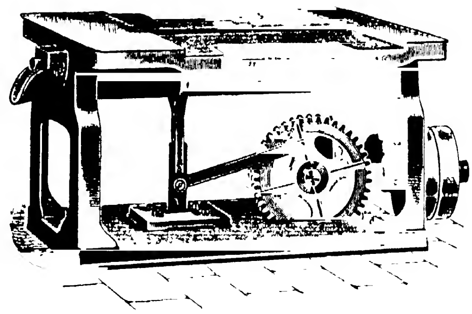


FIG. 55.—Cake-Paring Machine—Robert Middleton.

Various designs of automatic cake-paring machines are now coming into use.

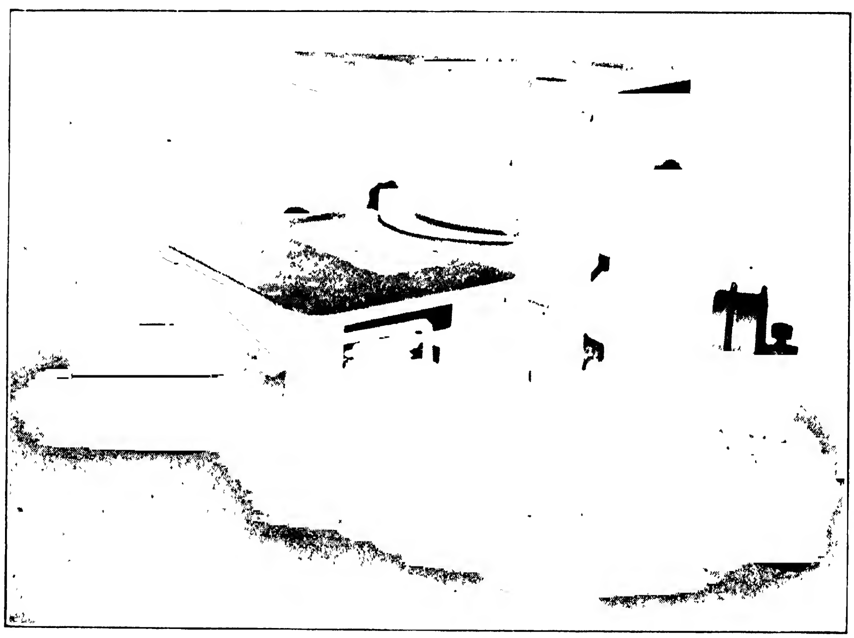


FIG. 56.—Hydraulic Cake-Paring Machine—Manlove, Alliott.

In a typical example the cakes, one by one from a pile, are moved forward against two knives set at the desired distance apart. Their movement is then continued at right-angles to the first traverse, so that the two remaining edges of the cakes may be

passed between a second pair of knives. Such a machine can readily deal with thirteen cakes per minute.

There is sometimes a little difficulty in getting a clean-cut edge with the above machines. Further, their operation calls for a certain amount of skill and judgment, and the cutting knives have to be carefully looked after. These considerations have led to the introduction of hydraulic paring machines. An example of this class, made by Manlove, Alliott & Co., Ltd., for paring the round cakes obtained from cage presses is illustrated in Fig. 56. In this machine the cakes, one at a time, are pushed against stops on the table underneath a power-driven revolving knife having saw-like teeth. When it is thus in position pressure is admitted to a hydraulic cylinder beneath the table. The ram head forces the cake against the revolving knife, which trims the cake by a combined shearing and cutting action. The cake, after being trimmed, remains within the circular knife, being held there by automatic catches. As succeeding cakes are trimmed the pile rises into the hollow top of the machine until, with each fresh cake fed to the knife, a trimmed cake is ready to be removed from the top of the pile. The ram is conveniently worked from the low-pressure accumulator, but if there is no such source of hydraulic supply the machine can be designed to utilise steam pressure. Similar machines are made for paring Anglo-American cakes. In these, of course, the action is one of pure shearing, the cakes being forced up against four fixed knives arranged at the edges of a quadrilateral opening in the machine head.

CHAPTER XI

EXTRACTION OF OILS BY CHEMICAL SOLVENTS

We now pass on to describe the second method of recovering oils from vegetable substances, namely, their extraction by means of chemical solvents, such as benzene, ether, chloroform, carbon disulphide, carbon tetrachloride—CCl_4—and tetrachlorethane—$C_2Cl_4H_2$. The idea of using solvents for this purpose is by no means a recent one. It was introduced as a practical process as long ago as 1843, by Fisher, of Birmingham. It is, nevertheless, true that only recently has the process come to be extensively adopted, for it has had to struggle against the prejudices inherited from its earlier and admittedly imperfect working. These prejudices are not yet by any means dead, and even in text-books of high standing statements are to be found concerning the results of the process which seem to be based on misinformation as to its modern state of development.

Objections Alleged Against the Process.

Before proceeding to describe modern examples of solvent extraction plant it is very desirable that we should deal with the objections which have been and still are, urged against the process. We may preface our remarks under this head by saying that in brief the process consists of allowing one of the solvents named above to percolate through the seed or meal in a closed vessel, heated or cold, of draining off the solvent and the oil which it has dissolved from the seed, of transferring the liquid to a heated still, and of the driving off the volatile solvent so as to leave the oil behind. The solvent driven off is condensed and used repeatedly.

The objections alleged against the process fall into three principal categories. In the first place it is argued that it extracts the oil so effectively from the seed that the residue of meal is next to useless as a cattle food and, at best, is fit only for manure. Secondly, it is stated that it is difficult or impossible entirely to eliminate all trace of the solvent used both from the oil and the residue of meal, so that the oil is made unfit for edible purposes and fit only for soap-making and kindred uses, while the nauseous taste or poisonous action of the solvent left in the meal provides a second reason why such meal should not be fed to cattle. In the third place, not one of the solvents used, it is said, is free from technical objections. Thus ether and chloroform are far too expensive to permit of their use commercially. This seems to be a sound contention. Carbon tetrachloride, it is urged, is also expensive and is apt to exercise a poisonous action on the workers attending the recovery plant. Further, while admittedly non-inflammable, it suffers from the great disadvantage that it very readily attacks metals. Regarding carbon disulphide, it is argued that while it is a very good solvent it is difficult to obtain pure and that it is apt to impart even to soap made from oil extracted with it an unpleasant sulphurous smell. It is further very readily inflammable, and, like carbon tetrachloride, exercises a poisonous action on those working with it. Against benzene the chief objection levelled is its inflammability. In addition it is stated to be the most difficult of all the solvents to eliminate from the oil and meal. Tetrachlorethane is a solvent of recent introduction. So far as we know it is not as yet in extensive use for the extraction of oils. It seems, however,

to possess certain features which may in time lead to its wide adoption. Thus, its commercial production appears to be simpler than that of carbon tetrachloride, while its action on metals is much less.

It must be admitted that certain of the above-mentioned objections are perfectly sound when applied to the process as carried out with old-fashioned apparatus—frequently of German origin—and using carbon disulphide as the solvent. As applied to modern British-made plant using benzene, as in the case of the system to be described, they appear to be quite out of date and in direct conflict with established fact. It is undoubtedly true that the process, as it can now be carried out, is rapidly being adopted on an extensive scale, a circumstance which seems to afford conclusive evidence that the objections summarised above are now recognised as being no longer valid.

The Objections Refuted.

In refutation of the objections urged against the process it may be directly stated that extracted meals are daily being used in large quantities both in this country and abroad as food for cattle, while a number of plants are at work in this country using the chemical solvent extraction process and producing nothing but oil of edible quality, as, for instance, oils which are used in the manufacture of first-grade margarine. Here we have evidence that all traces of the solvent used can now be eliminated, both from the oil and the meal. Whether or not the entire absence of oil in extracted meal lowers the value of the residue as a foodstuff is a very debatable point. There are distinct indications that a marked percentage of oil in a cattle food is not quite as great an advantage as it was at one time believed to be. This seems to be recognised by many cattle-feeders themselves and is supported by the views expressed in the recent report of the Government Committee on Oil Seeds, which views tend to the recommendation as a cattle food of extracted meal even when next to entirely free from oil. In explanation of this it may be pointed out that while oil is a heat former it is the albumenoids in the material that count from the actual food or flesh-forming point of view, and that extracted meal is richer in these albumenoids than the cake procured by pressing the same seeds.

Apart from this question it is to be noted that no oil cake is fed by itself to cattle. It is diluted with bran or other substance. The "other substance" may very well be extracted meal, which may be mixed with the cake to give a foodstuff of the desired oil content. In any event the argument against the extraction process, which is based on the deficiency of oil in the residue, entirely falls to the ground when we observe that under modern conditions the operator using this process can arrange to leave as much or as little oil in the residue as he may desire.

Advantages of the Process.

From the technical point of view the chief advantages attending the adoption of the process lie first in the comparative simplicity and cheapness of the plant required; secondly, in the small amount of power absorbed in driving the plant; and thirdly, in the fact that the labour demanded for its attendance need not be highly skilled. From the commercial point of view its full advantages can only be assessed by a careful study of certain factors which vary from place to place and from time to time. If it be a question whether the press or extraction system shall be adopted, everything turns upon whether or not the seed to be treated yields a residue which, quite apart from the process of recovery used, is in demand as a cattle food. Thus rape seed, even when treated by the crushing process, is not greatly valued as a cattle food. In such cases the only product primarily to be considered is the oil. This naturally

points to the adoption of the solvent extraction process as the better method of treating such material in view of the considerably higher yield of oil which it secures. A secondary consideration points in the same direction. If the residue of the seed is unsuitable as a cattle food, its only other important outlet is as a manure or fertiliser. Press cake has to be broken up and reduced again to meal before it can be used for this purpose. Extracted meal is suitable for it as soon as it is taken out of the extractor plant. Far more important than this, however, is the fact, now well established, that grease or oil in a fertiliser prevents the soil foods from being absorbed by the soil for, if present, it acts to defend the fertiliser against the attacks of those organisms which convert the constituents of the fertiliser into immediate soil foods. Clearly, then, the extraction process, eliminating as it can be made to do practically all oil from the residue, has very great claims to attention when the residue has to be used as a fertiliser.

If the seed residue, on the other hand, is suitable for cattle-feeding purposes, the first point to consider is whether there is a local market for it in this form. It may well be that there is not, and that, in view of the cost of shipping the residue to the nearest market, the balance is in favour of using the residue as a manure. Here again the adoption of the solvent extraction process is indicated as desirable. The conditions here touched upon arise very often when the recovery of the oil in the neighbourhood where the oil-bearing seed is grown is under consideration. This practice is desirable in itself, for the seed, being fresh, will almost certainly produce a better oil than it would after deteriorating during its journey to some distant factory. There is, however, probably no local or conveniently adjacent market for the residue as a cattle food, and this, up to the present, has led to the shipping of enormous quantities of oil-bearing seed for treatment in this and other countries remote from the country growing the seed. By adopting the solvent extraction process the grower can save freight charges by shipping nothing but oil, and can dispose satisfactorily of the residue by using it as a manure on his own plantations.

Commercial Aspect of the Process.

We thus see that the solvent extraction process has distinct claims to attention when :

(*a*) The residue is not usable as a cattle food by reason of the nature of the seed itself, and when

(*b*) The residue, although suitable for cattle feeding, is not usable in this way by reason of there being no market for it situated conveniently near the mill. A third case arises, namely, when

(*c*) The residue is usable as a cattle food, and can be conveniently disposed of as such. These conditions are met with, for example, when it is a question of treating linseed or cotton seed in this country.

Which process it is best to adopt under these circumstances is a matter for very close study. Several factors are involved. But in investigating the matter a certain line of argument frequently advanced by those interested in the solvent extraction process should not be too readily accepted. According to this argument it is poor policy to dispose of oil as a constituent of oil cake fetching £12 to £18 per ton, when, by extracting it completely, it can be sold for £40 to £60 per ton. This argument appears to be fallacious, in so far as it overlooks the fact that it is the custom of the oil-seed-crushing industry to charge for the oil cake in such a way that the oil in it reaps the same price as the bulk of the oil separated from the seed. Thus a

ton of linseed containing 40 per cent. of oil originally, after being crushed, appears roughly as—

	£	s.	d.
747 lb. oil: value, at £53 per ton	17	13	4
1,493 lb. cake: value, at £19 per ton	12	13	4
2,240	30	6	8
Cake: 10 per cent. oil.			
149 lb. oil: value, at £53 per ton	3	10	8
1,344 lb. dry residue: value, at £15 4*s*. 5*d*. per ton	9	2	8
1,493	12	13	4

Similarly, a ton of undecorticated Egyptian cotton seed containing 24 per cent. of oil originally will, after crushing, appear as—

	£	s.	d.
348 lb. oil: value, at £53 per ton	8	4	11
1,892 lb. cake: value, at £15 10*s*. per ton	13	1	9
2,240	21	6	10
Cake: 10 per cent. oil.			
189 lb. oil: value, at £53 per ton	4	9	4
1,703 lb. dry residue: value, at £11 7*s*. per ton	8	12	5
1,892	13	1	9

Clearly, then, so far as the money realised by his products is concerned, it does not matter to the oil crusher how much or how little oil he leaves behind in his cakes. He gets the same price for the oil whether he recovers it or allows it to remain in the cake. Were he to adopt the solvent extraction process he would not realise a penny more for the oil contained originally in the seed.

At the present moment in this country linseed and cotton seed are crushed rather than extracted, because a demand exists for linseed and cotton seed press cake containing a considerable percentage of oil. Rightly or wrongly, little or no demand exists for linseed and cotton seed extracted meal. On the other hand, rape seed is extracted rather than crushed, because no demand exists for rape seed press cake. The oil left in such cake would represent a sheer loss, for the cake could not be sold at a higher figure than the extracted meal. In addition, the oil left in the cake would, as we have already stated, lower the manurial value of the residue.

By way of conclusion to this brief discussion of the relative merits of the two processes, we need only remark that they should not be regarded necessarily as rivals. The solvent extraction process has a very distinct field of its own. Worked side by side with the crushing process, so as to recover the last portion of oil from the seed, it is of very great value in certain particular cases, as, for example, when the material to be treated is olives. As a direct alternative to crushing its importance is rapidly increasing. When the true value of extracted meal as a cattle-feeding stuff becomes more generally recognised the rivalry of the process with the crushing method will no doubt undergo great development.

The Ideal of the Process.

The ideal solvent extraction process, it can be said, should secure the complete recovery of all the oil in the seed—or as much of it as it is desired to recover—in one stage, and should leave the residue of the seed in a dry state. It may be remarked that certain extraction processes fall short of this ideal. in so far as the meal after extraction has to be separately dried.

Preparation of the Material.

Palm kernels, copra, soya beans, and similar materials are prepared for the extraction process in precisely the same way as for crushing, the only difference being that the flesh need not be reduced or shredded to quite the same degree of fineness. Seeds such as rape seed, linseed, etc., need only be lightly rolled. Cotton seed, castor seed beans, and similar material commonly decorticated before being crushed can, if desired, be extracted in an undecorticated state, the seed being simply rolled so as to break the cortex. The saving of the expense of decorticating results in considerable economy if the residue is to be used as a fertiliser, or if the skin or shell of the seed being treated possesses, as is sometimes the case, a distinct feeding value.

The "Scott" Extraction Plant.

One of the best-known forms of solvent extraction plant is that working on the "Scott" system, and made by George Scott & Son (London), Ltd., Kingsway House, Kingsway, London, W.C. Under this system the solvent commonly used is benzene.

Benzene—or benzol, as it is still frequently called in commerce—is, when pure, a colourless liquid having a specific gravity of about 0·88 at 15° C., and boiling under normal pressure at about 80° C. It is very slightly soluble in water, but is soluble in alcohol, ether, carbon disulphide, etc. On the other hand, it very readily dissolves resins, sulphur, phosphorus, fats, oils, and many alkaloids, and other organic compounds.

Two features of the "Scott" system may here be set down. In the first place, the extraction is performed in the cold, thereby practically eliminating all danger arising from the inflammable nature of the solvent used. Secondly, the extraction is effected partly by the solvent in liquid form and partly by it in the form of a vapour. In this respect, the system differs from others. In general the solvent is wholly in the form of a liquid, although it is evident that when hot extraction is adopted the solvent admitted as a liquid must at least in part become vaporised. The "Scott" system, therefore, may be said to combine the advantages of hot extraction with the safety of cold extraction.

In Plate V. we reproduce a drawing, specially prepared for us by Messrs. Scott, showing in diagrammatic form the plant used under the "Scott" system. Figs. 57, 58 and 59 show views of actual installations, while in Fig. 60 a small extraction plant suitable for trial and similar purposes is represented. Referring to the line engraving it will be seen that each extractor is fed with meal through a door at the top from an overhead hopper. The doors are, as indicated in Fig. 58, provided with hinged bolts, so that they may, when the extractor is charged, be readily and tightly fastened down. The hopper system of feeding the extractors economises labour, but entails the erection of a fairly heavy superstructure. In large mills it is sometimes found convenient to dispense with hoppers and to provide instead a conveyor with a suitable off-take to each extractor. This method has an additional advantage over the hopper system, in that by its adoption it is readily possible to feed the extractors with a mixture of seeds in any required proportion.

With many materials it is desirable that the mass in the extractor should be agitated while the solvent is at work. Figs. 57 and 58 and the diagram represent plants provided with agitating gear driven by means of a belt pulley, worm and worm wheel. The plant shown in Fig. 59 has no agitator. When the extraction process is completed, the discharge doors near the foot of the extractors are opened so that

the agitator may deliver the residue of the meal on to a conveyor which runs past the doors. This residue, it is to be noted, is, under the "Scott" method of working, quite dry and can, if required, be fed directly to cattle or horses, if the seed being treated renders this practicable.

General Method of Working.

During the period of extraction, the solvent, with the oil it has dissolved, is drained off from the foot of the extractor through the pipe A. Passing along the pipe B it reaches a steam-heated tubular vaporiser. Here a portion of the solvent is driven

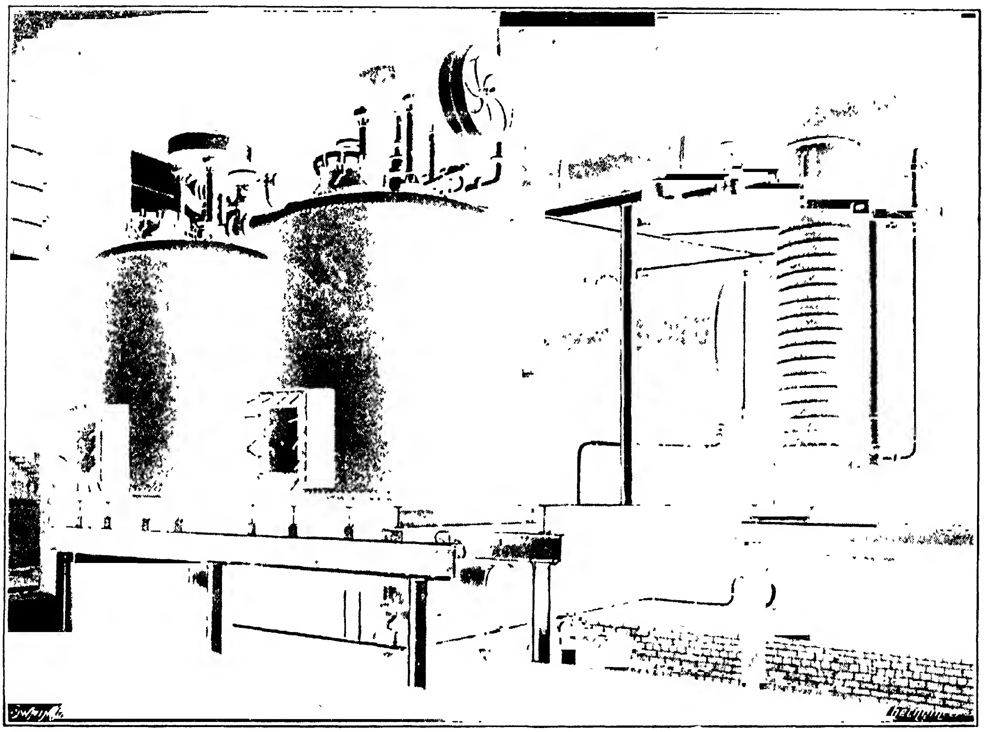


Fig. 57.—Benzene Solvent Extraction Plant—Scott.

off as vapour, and rising up the pipe C this portion enters the extractor at the top to act, as we have explained, in conjunction with the solvent admitted as a liquid. The remaining portion of the solvent with all the dissolved oil leaves the foot of the vaporiser at D, and flowing along the pipe E reaches a pump which lifts it up into a still-feed tank. Leaving this by way of the pipe F the liquid flows through a heater-condenser—or "heat exchanger"—and so reaches the continuous still, appearing like a column on the right of the engraving.

The construction of this still will be referred to shortly. For the time being it is sufficient to say that it completely drives off the solvent from the oil. The finished oil leaves the still at the foot as indicated. The solvent vapour finds its exit at the top through the pipe G. Flowing through the heater-condenser it is partially condensed by the contra-flowing liquid passing to the still, and, at the same time, assists the work of the still by pre-heating the incoming supply of liquid. Leaving the

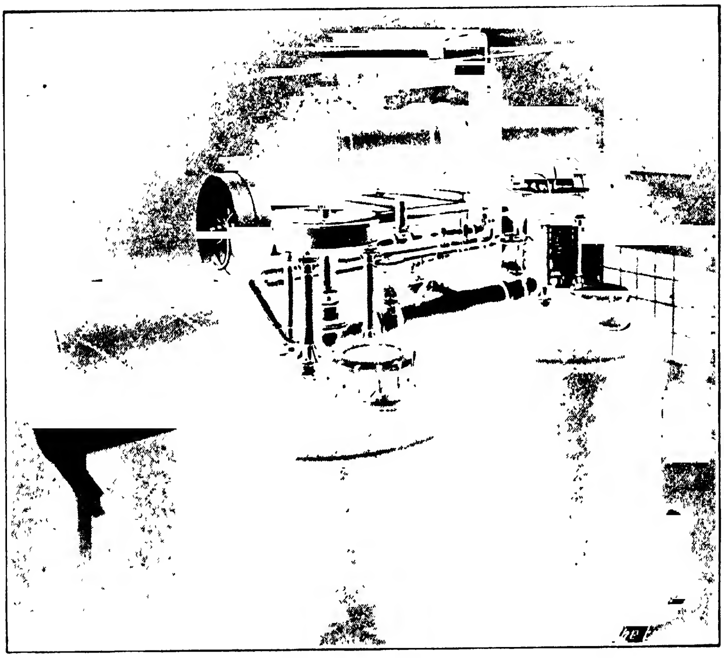


FIG. 58.—Scott Solvent Extractor with Agitating Gear.

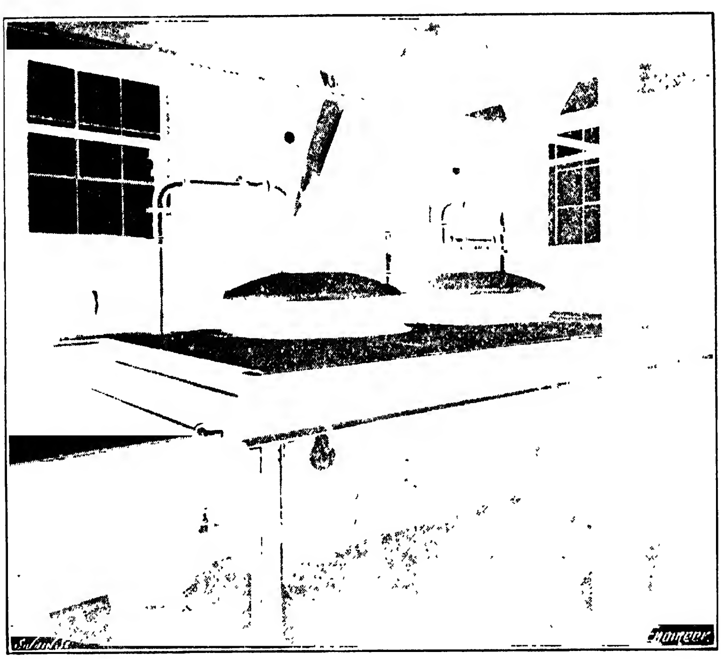


FIG 59.—Scott Solvent Extractor without Agitating Gear.

heater condenser the partially condensed solvent vapour is reduced completely to liquid in two condensers. On the way through the still, as we shall see presently, it has picked up some water. It is, therefore, taken by way of the pipe H to a water separator. The action of this separator depends upon the difference between the specific gravities of the solvent and water. The water flows off at the pipe J. The liquid solvent passes along the pipe K into a store tank ready for re-use.

It will thus be seen that of a given amount of solvent introduced into the extractor a portion is returned directly to the extractor as vapour, and a portion is delivered into the store tank ready for re-use. The former portion emerging from the extractor as liquid containing oil in solution again reaches the vaporiser. Part of it is returned once more as vapour to the extractor, and the remainder, passing through the still, is cleaned of dissolved oil and joins the first portion of the original charge of solvent in the store tank. Obviously, as time goes on, unless something is done, practically all the original charge of solvent will be found in the store tank; no vapour worth speaking of will be found ascending the pipe C, and the extraction process will come automatically to a standstill.

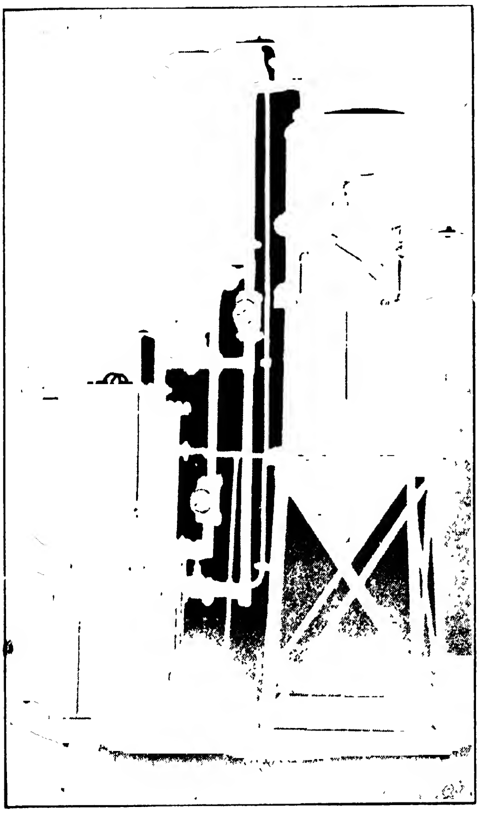


Fig. 60.—Small Solvent Plant.

This condition may or may not correspond with the complete recovery of the oil from the seed or with the degree of recovery desired. If it does not, a fresh quantity of clean solvent is passed into the extractor to complete the process or carry it a stage further. The manner in which this fresh quantity is introduced is the same as that in which the original amount of solvent is admitted into the extractor at starting up. It is conducted as follows :—The workman temporarily closes the valve L and opens the valves M and N. Clean solvent from the store tank now flows down the pipe P to the vaporiser. Partly as vapour it rises up the pipe C to the extractor, and partly as liquid it flows out at D to the pump which, lifting it, sends it along the pipe Q past the valve N into the extractor at R. When sufficient fresh solvent has thus been introduced, the valves are reset and the former process is resumed.

It is found that when the extraction of the oil from the meal is nearly completed, the solvent drawn off from the extractor contains very little oil. It is not economical to pass this poor liquid into the still. It is therefore sent into a " half-spent " solvent tank—not shown in the diagram—and is re-used as the first charge of solvent for a fresh charge of meal.

Cleaning the Meal of Solvent.

When the extraction is quite completed, and before the discharge doors are opened, the valves L and S are shut down and the valve T is opened. Steam, in a dry condition but not superheated, is then admitted to the extractor through the valve U. Blowing through the meal this steam carries off all traces of the solvent from the meal. The steam and solvent vapour rising up the pipe V reach the condensers, and traversing the water separator as before, are passed respectively to waste and to the store tank.

Alternative Method of Working.

The above description relates to the working of one extractor. The other extractor is worked similarly, the vaporiser and its connecting piping being duplicated for this purpose. Our description, further, covers only one method of working the plant. Modifications are provided for. Thus the vaporiser, once the original charge of solvent has been introduced into the extractor, can be completely cut out, so that the extraction may be performed entirely by liquid solvent. To achieve this the valve L is held closed and the valves W and the valve N opened. The solvent, with its dissolved oil now reaches the pump without passing through the vaporiser, and is sent back to the extractor along the pipe Q. After it has been circulated through the meal a sufficient number of times it is sent into the still feed tank by closing the valve N.

Safety Valves.

With plant of this nature it is very important to provide safety valves at all points where pressure might conceivably accumulate, and at the same time to provide means whereby this pressure may be relieved without allowing any of the inflammable solvent vapour to escape into the atmosphere. The points at which excess pressure might possibly accumulate are in the vaporisers, in the extractors, and in the still. Safety valves are therefore provided at X, Y, and Z, respectively. It will be noticed that the two safety valves X are connected by a horizontal pipe having union with the pipe V, up which the cleaning steam passes at the termination of the extraction process. Excess vapour passing the safety valves X does not escape into the atmosphere, but into this horizontal pipe, and so reaches the condensers. A similar arrangement is provided for the safety valves Y. The safety valve Z for a similar reason is arranged on a by-pass bridging the stop valve for the still, and delivers any excess vapour escaping past it through the heater-condenser into the main condensers. There is little danger of any accumulation of pressure within the condensers or store tank. But, in any event, the water separator acts as a seal to both, and therefore as an emergency pressure-relieving device. On the top of each vapour pipe C a deadweight safety valve is provided with outlet direct to the atmosphere. This is a purely precautionary measure. The valve is set to a few pounds above the release pressure of the valve X, and is intended to come into use should the latter valve, for any reason, fail to act. So far as Messrs. Scott know these deadweight safety valves have never yet on any of their plants been called upon to fulfil their function.

The Continuous Still.

The separation of the solvent from the oil is begun in the vaporiser. This is done simply to take incidental advantage of the steam required to generate the vapour for the extractor. The main and final separation takes place in the still. This separation is a most important feature of the process, for on its completeness must largely depend the commercial value of the oil recovered. Very frequently this separation has been

attempted in stills of the pot or bulk charge type. This method of working occupies a considerable amount of time, a fact important in itself and also in its bearing upon the effect which contact with heat for a prolonged period has upon most oils. In addition, towards the end of the operation there is little solvent to remove, so that during this time the steam used to drive off the solvent cannot be used with full efficiency. Thus fuel is wasted, and an unnecessary tax is placed on the condensers which collect the steam and solvent vapour.

The still shown in the diagram is of a form recently patented by Messrs. Scott. A number of these stills are already satisfactorily at work on the production both of edible and of trade oils. The "Scott" still is divided into a number of sections, each of which is a still by itself. The oil and solvent mixture heated in the "heater-condenser" to approximately the distilling temperature enters the top section of the still and passes downwards in turn through each of the others. In so doing it comes into direct contact with an ascending current of steam admitted below the bottom section of the still and baffled in such a way as to cause it to take a tortuous course through the descending liquid. As the steam rises it liberates the solvent as vapour, which vapour assists the steam in distilling the solvent from the liquid passing through the next highest section of the still. It will be seen that under this method of working the freshest steam is caused to act upon the liquid with the least amount of solvent in it, that is to say, in the liquid at the time when it contains those last traces of solvent which are the most difficult to remove. At the top of the still the steam, partially used up, is given the easiest work to do, namely to attack the liquid when it is richest in solvent, and therefore has the lowest boiling-point.

Working Charges.

It is claimed for the "Scott" system that very little labour is required to run the plant. The proportion which the labour charges will bear to the other working costs depends, however, on the size of the plant, for while the size varies, the number of men required to operate it remains constant. It is stated that the very largest plants consisting of many extractors can be operated by two men. Economy of steam consumption is another point connected with the plant to which the makers call attention. The coal required per ton of raw material, we are informed, may be set down as from 2 to 3 cwt. The only other item of working costs to be considered relates to the solvent. It is found that in operation a certain amount of solvent disappears; where it goes to is by no means clear. This loss may be returned at 1½ gallons per ton of material treated.

It is, perhaps, worth adding that the solvent extraction process has to-day a very wide field of application outside of the vegetable oil industry. It is being employed for the extraction or recovery of grease, oil, or fat, from many miscellaneous substances, such as wool waste, bones, leather scrap, rags, factory sweepings, and refuse of all sorts.

CHAPTER XII

THE REFINING OF OILS

We now come to a section of our subject concerning which a great deal of secrecy is commonly exercised. Oil refining is usually carried out in works quite separate from the mills producing the oil. It may, in fact, be properly regarded as constituting an industry by itself. It requires the possession of a considerable knowledge of chemistry, for each oil in general has to be treated in a special manner. The refining may be carried out to varying degrees of completeness. According to its degree, so does the enhanced price obtained for the oil vary. As a rough guide, however, it may be said that refining increases the value from, say, £5 per ton, as in the case of rape oil, to anything up to £10, as in the case of cotton seed oil.

A perfectly pure oil is a definite chemical body. It may be regarded as being formed by the union of a molecule of glycerine with a molecule of fatty acid accompanied by the withdrawal of a molecule of water. The glycerine is definitely constant from oil to oil. The fatty acid varies from oil to oil, and by its variation gives the oil its characteristics. All pure oils, such as we are for the moment considering, are probably identical, in so far as they are colourless, odourless and tasteless. Crude oils differ from pure oils in three principal respects. In the first place, they may be coloured. The colouring matter is derived either from the fleshy portion of the seed from which the oil is recovered or from the husk of the seed, if this is crushed along with the fleshy portion. Secondly, crude oils contain vegetable fibrous matter or mucilage or other foreign bodies crushed out of the seeds along with the oil. Such mucilage is simply suspended mechanically in the oil. Thirdly, they may contain free fatty acid and free glycerine, caused by some portion of the oil absorbing water and splitting up. This splitting-up process, or hydrolysis, as it is called, is frequently caused by careless or crude methods of manufacture, as in the case of palm oil. Even, however, with the most careful manufacture, some fatty acid is nearly certain to be present in the crude oil, the reason being, apparently, the hydrolysis of the oil by natural processes in the seed itself before it is crushed—possibly even before it is gathered. The presence of free glycerine in an oil is rarely objectionable, for it is colourless, tasteless and odourless and stable. The presence of free fatty acid is nearly always objectionable, for to such may usually be attributed the characteristic taste and smell of an oil, while in addition, its decomposition turns the fat or oil rancid. The possibility of such acid being present is the prime reason why vegetable oils are not in favour as lubricants.

In addition to the removal of mucilage, of colouring matter, and of free fatty acid, oil refining frequently includes a fourth class of operation. On a cold day certain qualities of olive oil will be noticed to throw down a flocculent whitish deposit. Cotton seed and other oils likewise become cloudy when the temperature falls. This deposit is "stearine"—or "margarine," as it is frequently and somewhat unfortunately called—and its removal is desirable in certain circumstances, notably so if the oil is to be used for burning, lubricating or edible purposes. The "stearine" itself is a valuable substance when isolated, and is made use of in the manufacture of candles, margarine, margarine cheese and lard substitute.

The processes employed in oil refining are either mechanical or chemical, or a

combination of both. Thus mucilage is removed mechanically. Bleaching is in general effected chemically, but is frequently accomplished by what is really a mechanical process. Free fatty acids are removed by a chemical reaction. "De-margarination" is most frequently effected by physical processes.

Preliminary Refining in the Oil Mill.

A certain amount of preliminary refining is commonly conducted on the oil before it leaves the oil mill. This refining aims only at the removal of the mucilage, etc., in the oil. Formerly, it was conducted simply by storing the oil for prolonged periods, sometimes extending to years, in storage tanks, wherein the foreign matter gradually

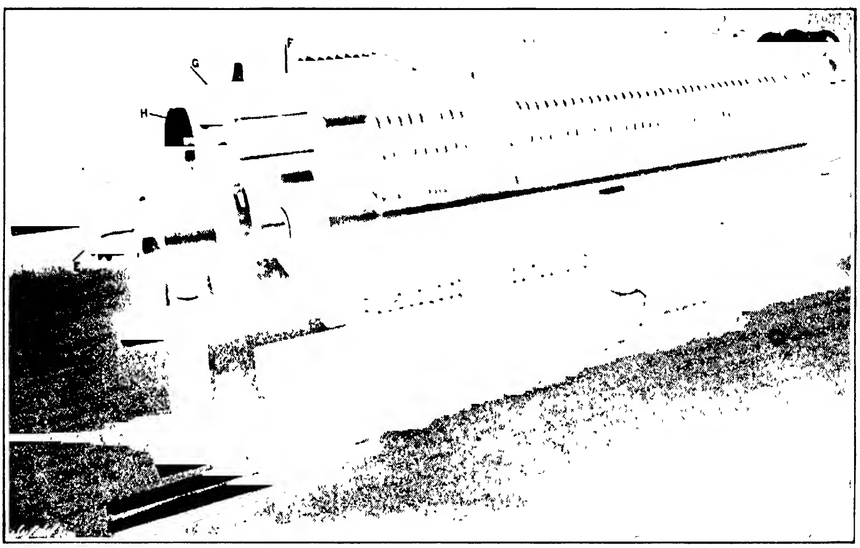


Fig. 61.—Filter Press for Oil—Manlove, Alliott.

fell to the bottom, leaving the clear oil on top. Modern practice now makes use of filter presses, and so very greatly economises both time and space.

Filter Presses.

The filter press is used in many industries for effecting the separation of solids from liquids. It is made in several modifications, but always follows the principle of forcing the liquid to be filtered through a layer of cloth, swansdown or twill. A filter press suitable for use in an oil mill is illustrated in Fig. 61. It consists primarily of a series of cast-iron plates formed with a lug at each side, which lugs support the plates on a pair of steel rods—usually circular—extending between the two fixed ends or pedestals of the press. In the form of plate shown in Fig. 62 an edge is raised up all round the periphery of each face, so that when two plates are brought together the dished centres form a chamber between them. Through the centre of each plate a circular feed hole is formed for the oil. The method of working will, perhaps, be understood with the help of the sketch, Fig. 63. For each plate there are provided two filtering cloths A, B, formed with central holes and united round the edges of these holes by means of a short cylinder or ring of cloth C. The cloth A can readily be rolled

up, slipped through the central hole in the plate and spread out flat on the other side. The two cloths to facilitate the assembly of the plates are then held at their upper edges by means of clips D passing on to a rib formed across the top of the plate.

When all the plates, thus clothed, have been assembled in the framework of the press, the pinion E (Fig. 61) is rotated by means of a tommy-bar inserted in holes round its flange. This pinion engages with a rack extending from the sliding head F, so that the action results in the press plates and their cloths being closed up together. The final closure of the plates is effected by turning down the half-covers G and screwing up the hand wheels H by means of levers. The chambers between the plates are thus sealed by nipping the cloths between the raised edges. Crude oil is now pumped into the press at the right-hand end, and flowing through the central feed holes fills all the chambers between the plates.

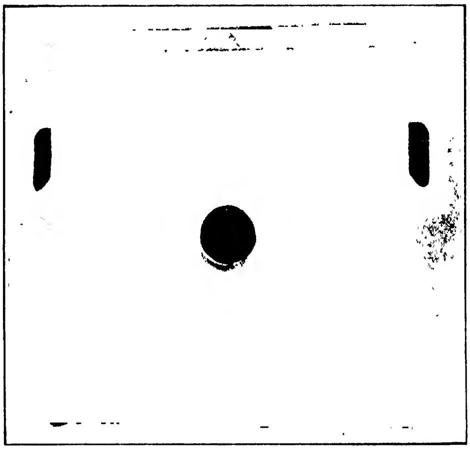


FIG. 62.—Filter Press Plate.

Under the pressure of the oil the filter cloths are pressed backwards until they meet the support of the plates. The faces of the plates, as shown in Fig. 62, are formed with vertical grooves connected by short horizontal grooves, so that the oil filtering through the cloths may trickle downwards into a gutter formed along the plate just above the lower raised edge. From this it is conducted through three holes into a central passage way J (Fig. 63), and so through cocks K (Fig. 61) into a collecting trough.

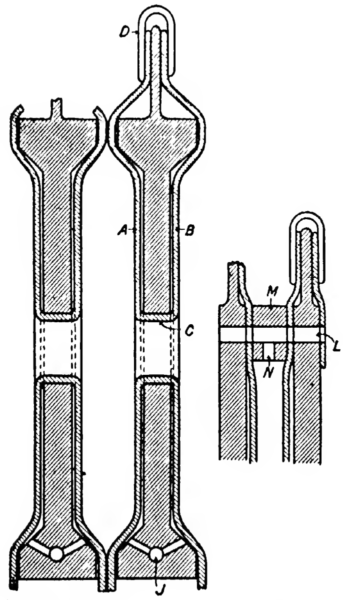


FIG. 63.—Two Forms of Filter Plates.

Instead of joining the two cloths for each plate by a ring of cloth, the cloths may be entirely separate. The central holes in the cloths are then nipped to the edge of the feed hole in the plate by means of a clip either of a screw or bayonet-fastening type. Yet another alternative method, one finding considerable favour, is to form the raised edges of the plates as a separate frame having lugs, like those on the plates, for their independent support on the two horizontal bars. This design of press is that actually shown in Fig. 61. The feed holes, as indicated at L in Fig. 63, are in this form placed near the upper edge of the plates, and are continued through the loose frames M. A hole N conducts the oil from the feed passage into the chambers between the plates. The cloths are placed between the loose frames and the plates. In this way the edges of the plates and the feed holes are sealed simultaneously when the press is screwed up. This design has certain advantages when it is desired to remove in one piece the cake left on the cloths.

The method adopted for closing the press plates also varies a good deal. Thus it may, in addition to the manner shown in Fig. 61, be effected by means of a central screw or a compressed air cylinder, or a hydraulic ram. In connection with the feeding of the press with crude oil considerable attention has to be devoted to the fact that the filtration towards the end of the operation becomes slower, so that a lessened feed is required. If the press is fed by means of a belt-driven pump, a relief valve should be provided on the feed pipe, so that with the pump running uniformly some of the feed may be by-passed when the speed of filtration falls off. A steam-driven pump

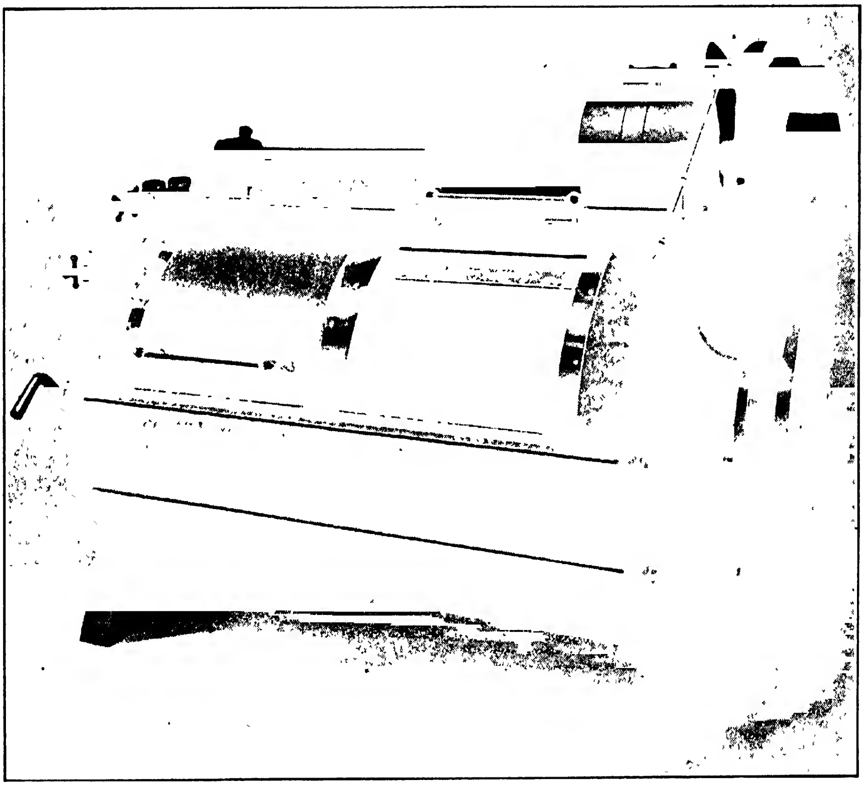


FIG. 64.—Washing Machine for Filter Cloths—Manlove, Alliott.

can be itself regulated to suit this requirement, and therefore does not require the provision of a relief valve. A better method than either seems to be the adoption of a forcing ram worked by compressed air. The flow in this case is stated to be entirely self-adjusting.

As usually supplied these filter presses may have anything from six to forty-five chambers, the dimensions of the plates varying from 13 in. to 40 in. square. The thickness of the cakes left in them is from 1 in. to $1\frac{3}{8}$ in. Little can be said as to the output, for this varies from oil to oil, and with the one oil, according to its previous treatment, and whether or not it is filtered hot or cold. As a guide, however, it may be said that a press with twenty-four chambers and plates 25 in. square—giving a total filtering area of 208 sq. ft.—may be expected to filter in twenty-four hours 140 cwt. of linseed cocoa-nut, or fresh olive oil ; 100 cwt. of crude cotton oil ; 70 cwt. of crude rape or

stale olive oil; or 16 cwt. of castor oil. The length of time for which the press will work without being opened for cleaning also depends upon the nature of the oil being filtered. In the case of linseed oil the press may be run continuously for about a week. It would then be allowed to stand with the pressure removed from it for, say, three hours, at the end of which time it would be opened up and the cakes formed in the chambers removed. Thereafter it is ready for a further run.

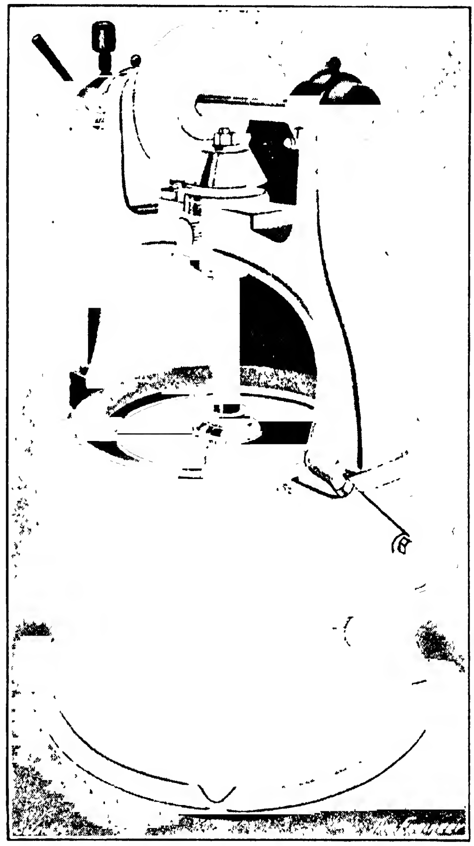


Fig. 65.—Centrifugal Extractor for "Foots."

Filter Cloth Washing Machine.

Occasionally, and particularly when the production of edible oils is in question, it is desirable to remove the press filter cloths and wash them. A washing-machine for this purpose is illustrated in Fig. 64. In this machine the cloths are treated in a hot dilute solution of caustic soda which, combining with the oil, produces soap and so cleanses the cloths from mucilage and dirt. The machine has an outer casing of galvanised steel fixed to two cast-iron ends. The internal rotary washing compartment is constructed of hard-rolled brass plates perforated from the inside in a special manner so as to avoid the creation of burrs. Five lifters or rubbers are provided inside the drum, while in the larger sized machines, such as that illustrated, there is a central partition. The outer casing and the inner drum are both provided with segmental doors sliding in brass guides. Hand-turning gear is provided for bringing the two sets of doors into alignment for loading and unloading purposes. The shaft carrying the washing compartment passes through glands in the cast iron ends of the casing, and is supported externally in adjustable roller bearings. It is driven through a silent rocker chain from a shaft at the back of the machine. This shaft carries two loose pulleys for crossed and open belts, and a fixed belt pulley. A worm and a worm wheel gear is provided automatically to move each belt alternately on to the fixed central pulley, so that the direction of rotation of the washing compartment may, during a run, be reversed at regular intervals. Steam and hot and cold-water valves are arranged on the casing in order that the cloths may be washed, boiled, and rinsed. A full bore waste outlet is also provided. After the cloths have been removed from the machine they are placed in a centrifugal hydro-extractor, which removes the bulk of the water. Thereafter they may be thoroughly dried, if thought necessary, in a steam-heated hot-air rotary drying machine.

The Treatment of "Foots."

In all oil mills, whether the presses in use are of the Anglo-American or the cage type, a considerable amount of meal saturated with oil escapes from the press and

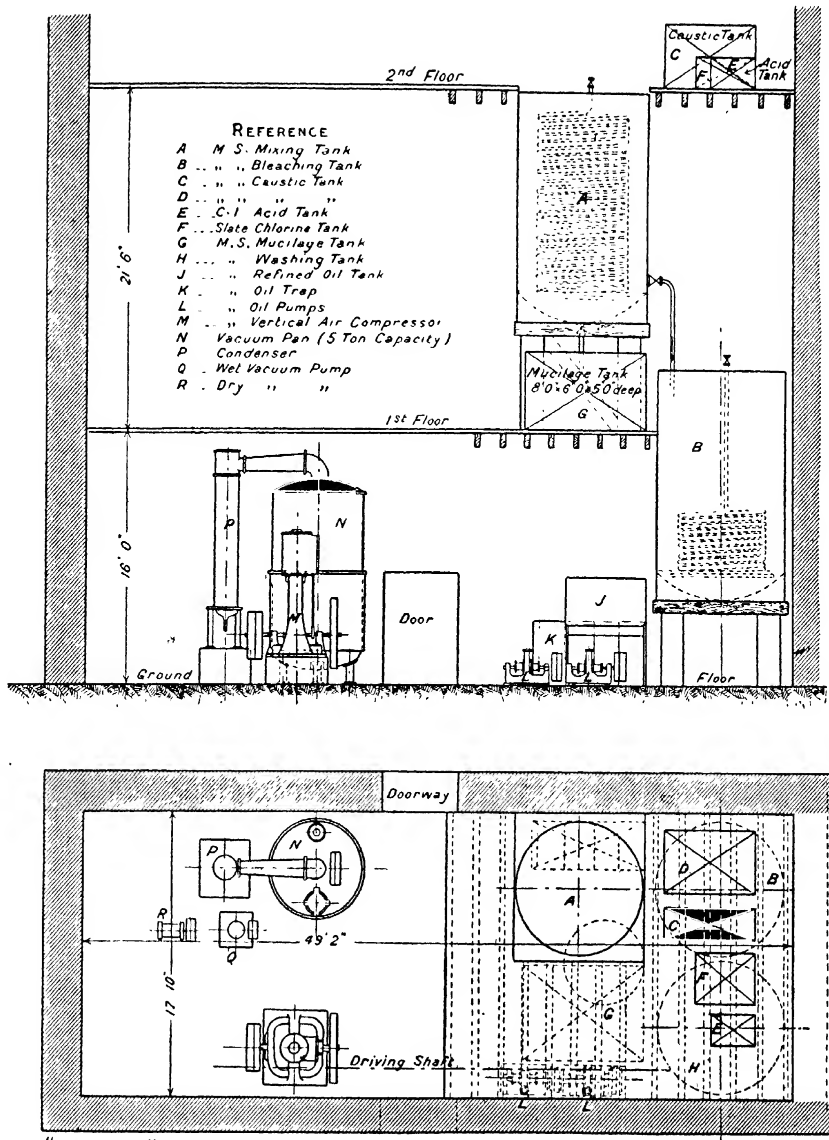


Fig. 66.—Cotton-Seed Oil Refinery—Manlove, Alliott.

accumulates in the tanks in which the presses stand, the oil dishes, and so on. This material is known as "foots," and to avoid waste is treated so as to separate the bulk of the oil from it. A common method of effecting this separation is by the employment of a "centrifugal" such as is shown in Fig. 65. This machine consists of a cast-iron

casing enclosing a basket of tinned-steel wire with a pressed-steel top ring and bottom. The basket is mounted on a vertical shaft supported at the top and bottom on ball bearings, and driven through friction cones from a horizontal cross-shaft. The peripheral speed of the basket is usually about 9,000 ft. per minute. The slurry is placed within it, and in a very short time the bulk of the oil is driven off out of the basket. This oil may be mixed with that extracted in the usual way or sold separately. The residue in the basket is found to contain about the same percentage of oil as does the original seed before pressing. It is therefore returned to the meal kettle and worked back to the press with the fresh meal.

In addition to the preliminary separation of mechanical impurities carried out as mentioned above, the refining of oil comprises the removal of free fatty acids and of bleaching to get rid of the colouring matter. Broadly, it may be said that the removal of the free fatty acids is necessary if the oil is to be used for edible purposes, and that bleaching is desirable if it is to be used for the manufacture of paints or varnishes.

Removal of Free Fatty Acids.

By removing the free fatty acids from the crude oil, the oil is deprived of the elements which give it its characteristic odour and taste, and which render it liable to decomposition. At the same time its colour will probably be improved, for the free fatty acids are a cause of discoloration in addition to the colouring matter absorbed by the oil, during its extraction, from the husks of the seeds.

The standard method of removing the fatty acids is to treat the crude oil with caustic soda solution, carefully regulated in strength and amount, and at a carefully regulated temperature. The soda solution combines with the free acids to form a soap, but is not sufficient in amount to go farther and saponify any material amount of the neutral oil. It is here to be noted that more caustic soda has to be added to the oil than is theoretically necessary to neutralise the percentage of free acid revealed by analysis in the crude oil. The surplus soda does not, however, attack the neutral oil unless of course it is permitted to be present in an altogether excessive amount. The reason, both for the procedure and of the result, lies in the fact that the action between a given amount of caustic soda and a given amount of oil will cease at a point, short of completion, at which a state of equilibrium is established between the amount of soap formed and the amount of oil and of caustic soda still left uncombined. The point in question is influenced by the temperature at which the reaction is conducted.

On the neutralisation of the free fatty acids being completed, there is thus left in the refining kettle a mixture consisting of soap, acid-free oil and caustic soda in solution. This mixture is allowed to stand for some hours to permit the soap, soda solution and any mucilage or albuminous matter to sink to the bottom, while the oil rises as a clear liquid to the top. The clear oil is then drawn off for further treatment. The residue at the foot of the kettle, containing as it does, a certain amount of neutral oil besides the soda, etc., is removed separately, and is sold to the soap maker as "soap stock." To facilitate the settling out of the soap, etc., from the oil, salt is sometimes thrown into the kettle, for soda soap is insoluble in salt water.

The clear oil has next to be washed with water to remove all traces from it of the soda. Thereafter it is treated in a vacuum still to drive off any volatile fatty acids which may linger in it, as well as the last traces of moisture left in it by the washing process. A vacuum still is used in order that the volatile acids and the moisture may be driven off at a temperature below that which will deleteriously affect the oil.

Bleaching.

The oil may or may not now have to be bleached. If it is to be used for edible purposes, it is desirable that it should be bleached by means of fuller's earth or such-like absorbent material. For other purposes chemicals liberating chlorine or oxygen may be used.

Treatment with fuller's earth, animal charcoal, etc., not only helps to bleach the oil; it also assists in deodorising it. The process consists in thoroughly stirring

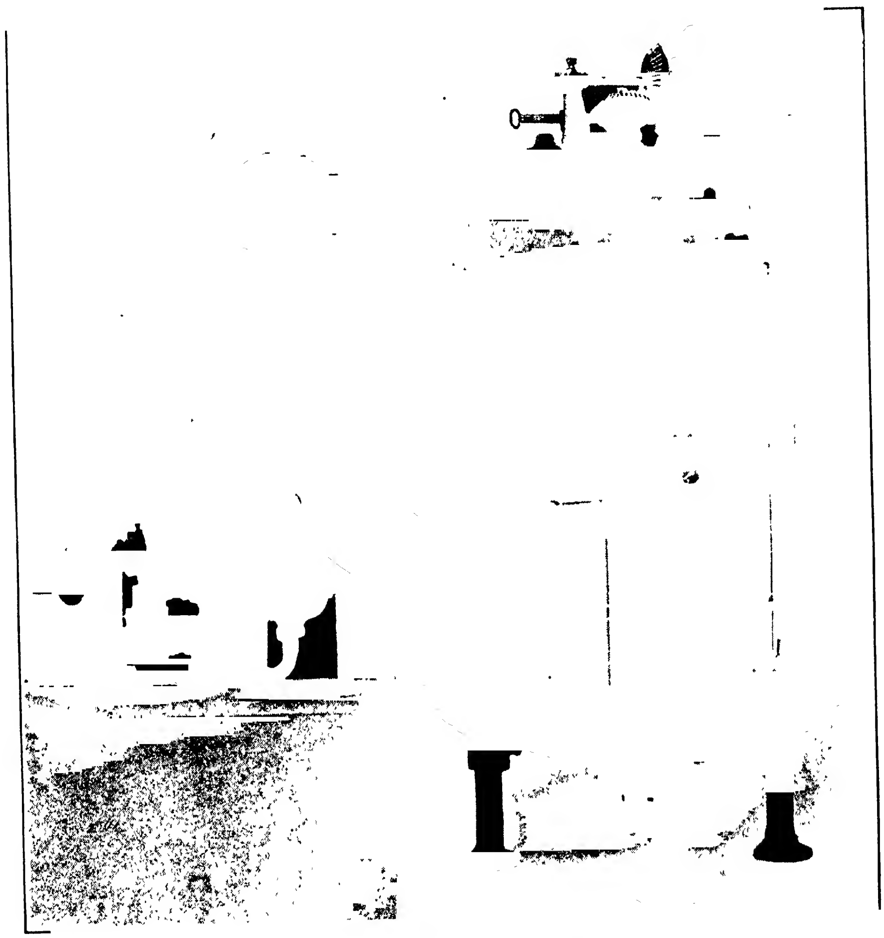


Fig. 67.—Vacuum Pan and Condenser.

the dry absorbent powder into the oil when gently heated and, after agitation for a short time, in passing the liquid through a filter press such as we have described above. The earth or charcoal with the absorbed colouring matter is retained on the filter cloths, while the clear oil is drawn off. The filter press is usually arranged to permit steam to be blown through it after filtering is completed. In this way the cakes are washed free from oil, so that on the press being opened the earth falls out as a powder.

It may surprise some to learn that oils can be bleached in the above purely mechanical manner. The explanation of the matter lies in the fact that the colouring

substance in the original seed is, in general, in the form of a powder, and passes as such into the oil. It can therefore be absorbed and held back by the earth or charcoal. It will be noticed that this method bleaches the oil by the direct removal of the colouring matter. A similar end is achieved by the sulphuric acid method, which is applied occasionally for bleaching certain oils. The acid dehydrates or chars the colouring matter and other impurities, and causes them to coagulate, so that they may readily be removed by filtration or sedimentation. This treatment incidentally secures the removal of any moisture in the oil, by reason of the strong attraction for water possessed by sulphuric acid. As, however, some acid may remain behind in the bleached oil, the method is not usually adopted if the oil is to be used for edible or lubricating purposes.

Bleaching by means of chlorine or oxygen does not secure the removal of the colouring matter. The colouration is destroyed by the oxidation of the colouring matter, but this, when oxidised, is allowed to remain behind in the oil. The chemicals used are, in general, such as to render the process unsuitable for application to the treatment of an edible oil. In most cases the oxygen or chlorine is generated by chemical reaction within the oil itself. Thus bleaching by means of oxygen may be effected by adding to the oil manganese dioxide and sulphuric acid. Similarly, chlorine may be generated by adding bleaching powder and hydrochloric acid. In one case manganese sulphate, and in the other calcium chloride, is left behind in the oil, and has subsequently to be removed by washing. Further, in both cases the reaction of the chemicals results in the formation of water.

Many other methods of bleaching oils by means of chemicals, or otherwise, are practised or have been proposed. It is not necessary for us here to discuss these, for they belong more to the chemical than to the engineering side of our subject. We need only remark that one of the oldest and one of the very best methods is by exposing the oil to the action of sunlight and air. This process results in the natural oxidation of the colouring matter, and is extensively adopted in the case of linseed, poppy and walnut oils, as used by artists. It is, of course, a very slow method. Recently, the bleaching of oils by means of ultra-violet rays has attracted some attention.

Cotton Oil Refining.

The arrangement of a typical refinery for treating cotton-seed oil is reproduced in Fig. 66. The oil in this case is first heated by steam in a mixing tank A until it reaches a temperature of about 140° F. Thereafter the oil is violently agitated by means of compressed air, the temperature, meanwhile, being kept as near 140° F. as possible. During the agitation caustic soda solution from the tanks C, D, is run into the mixing tank. As this solution, being heavier than the oil, tends to sink to the foot, care is necessary if it is to be brought properly into intimate contact with the oil. This is secured by distributing the solution evenly over the surface of the oil, and by the vigorous agitation to which the contents of the mixing tank are subjected. When it has been ascertained by testing samples that sufficient caustic soda has been added to neutralise the acid reaction of the oil, the charge is allowed to stand and settle in the mixing tank. The settling is usually sufficiently complete at the end of about twelve hours to permit the clear supernatant oil to be drawn off and passed into the washing tank H. In so doing, great care has to be exercised that none of the residue is passed off with the clear oil. This residue is ultimately drained into the mucilage tank G.

In the washing tank the oil is gently heated and washed with water to remove the caustic soda solution remaining in it. The water is distributed uniformly over

the surface of the oil, which, as before, is violently agitated by means of compressed air jets. On allowing the charge to settle, the oil rises to the top. The water containing the soda in solution sinks to the foot of the tank and is drawn off. For the production of the best edible oils two or three washings may be required.

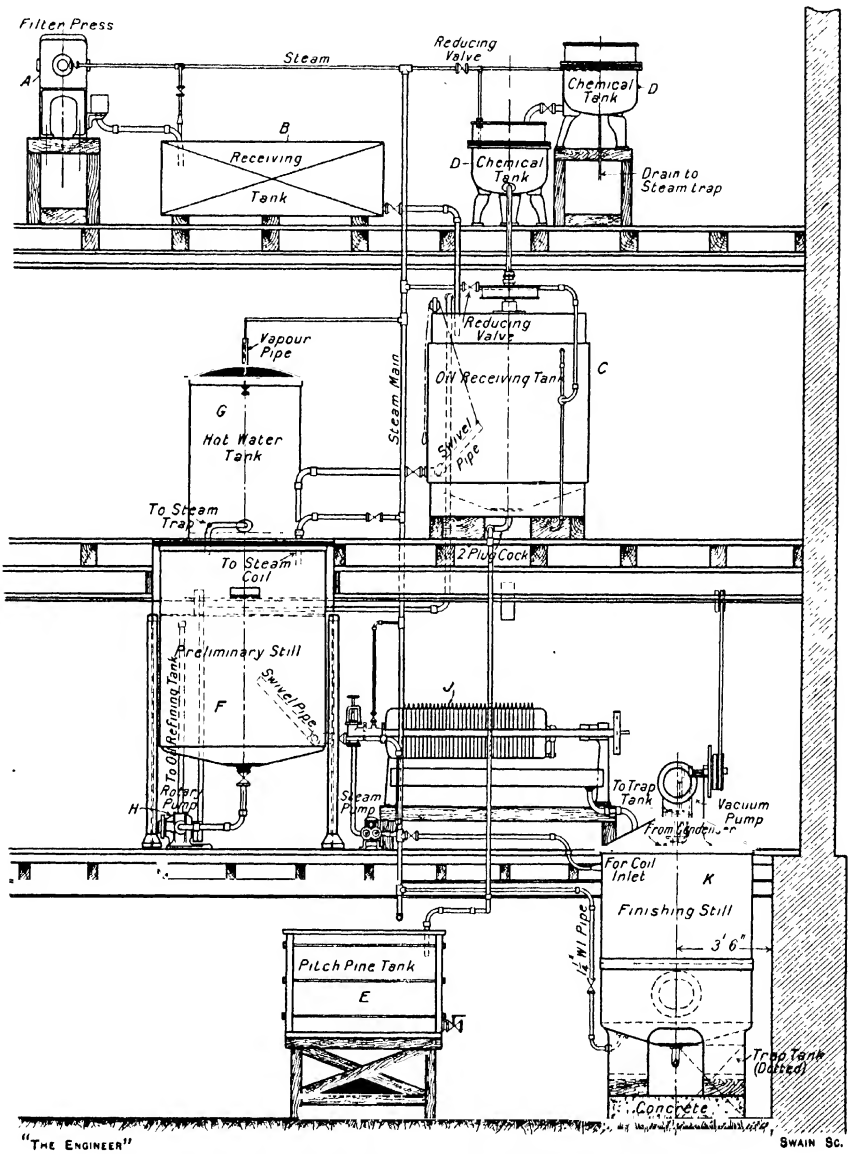


FIG. 68.—Cocoa-nut Oil Refinery—Manlove, Alliott.

If the oil is for edible purposes—say for the manufacture of margarine or lard substitute—it will either be passed without being bleached into the vacuum pan N or will be bleached by the fuller's-earth method already referred to. Oils for other than edible purposes are passed from the washing tank into the bleaching tank B.

Here they are agitated in the usual way and are subjected to the joint action of hydrochloric acid delivered from the cast-iron tank E, and of bleaching powder solution drawn from the slate tank F. When bleaching is completed, the charge is returned to the tank H, wherein the bleaching chemicals and the salts formed by them are washed out of it. The procedure may be slightly varied by passing the oil direct from the tank A into the bleaching tank. This avoids the first washing, but results in a certain amount of acid being wasted in the neutralisation of the caustic soda solution remaining in the oil. This neutralisation, it may, however, be noted, results in the production of sodium chloride, the presence of which in the oil is by no means harmful, but frequently of assistance.

The oil drawn from the washing-tank is now passed into the vacuum pan N—shown separately in Fig. 67. Here it is mechanically agitated and heated under a vacuum, so as to drive off the moisture and any free volatile fatty acids which may yet remain in it. The expelled products are caught in the condenser P. If the oil is an edible oil, and if it is required in a bleached condition, some refiners combine the fuller's-earth treatment with the treatment of the oil in the vacuum pan. On leaving the pan, the oil is, in such a case, passed through a filter press, whereafter it is ready for the market.

Cocoa-nut Oil Refining.

A small refinery for cocoa-nut, palm kernel and similar oils is illustrated in Fig. 68. The procedure in this case is, in principle, similar to that followed in the cotton oil refinery described above, except that no provision is made for bleaching the oils chemically since they are here intended solely for edible purposes.

The oil, as received, is first passed through a filter press A to remove mucilage, etc., and is thence run into a storage tank B. From this it is passed by gravity into the refining tank C situated on the floor below, where it is heated, agitated, and treated with caustic soda solution from the tanks D in the usual way. After settling, the mucilage and other residue is drawn off into the pitch-pine tank E situated on the ground floor, while the clear oil is passed into the tank F on the first floor. In this tank F the oil is washed with hot water from the tank G and is, in addition, heated by means of a steam coil. The tank F, in fact, not only serves for washing the oil, but also acts as a preliminary still for driving off a certain amount of the volatile free fatty acids which yet may linger in the charge. By means of a rotary pump H, the charge in the tank F can be sent back to the refining tank C, so as to be returned to the tank F for further washing and heating. The oil, previously treated with fuller's earth or not, as is thought desirable, is passed from the preliminary still F through a second filter press J, and thence into a finishing still or vacuum pan K of the design illustrated already in Fig. 67.

Demargarination.

Certain oils, notably cotton-seed and olive, as we have already remarked, throw down a deposit of "stearine" when the temperature falls below a certain point. Chemically, an oil is formed by the union of a fatty acid with glycerine accompanied by the withdrawal of a certain number of atoms which, taken together, constitute water. The body formed by such a union is known as a glyceride. A glyceride is thus an oil, but no actual oil, so far as we know, is formed of one and only one glyceride. Stearine is a glyceride, being formed by the union of stearic acid with glycerine. Palmitine—palmitic acid and glycerine—is another. And there are many more,

such as oleine, linoline, linolenine, and so on. These glycerides solidify at different temperatures. Thus, of those mentioned, stearine and palmitine may be said to have relatively high solidifying points, and oleine, linoline and linolenine, relatively low solidifying points. Taking the particular case of cotton-seed oil, we find that this oil consists principally of a mixture of palmitine, oleine and linoline. When the temperature falls, the palmitine solidifies out, while the oleine and linoline are still liquid. The " stearine " deposited by cotton-seed oil is, therefore, not stearine, but palmitine. From other oils—for example, from olive oil—it may consist of a mixture of true stearine, palmitine, and other glycerides solidifying at a relatively high temperature.

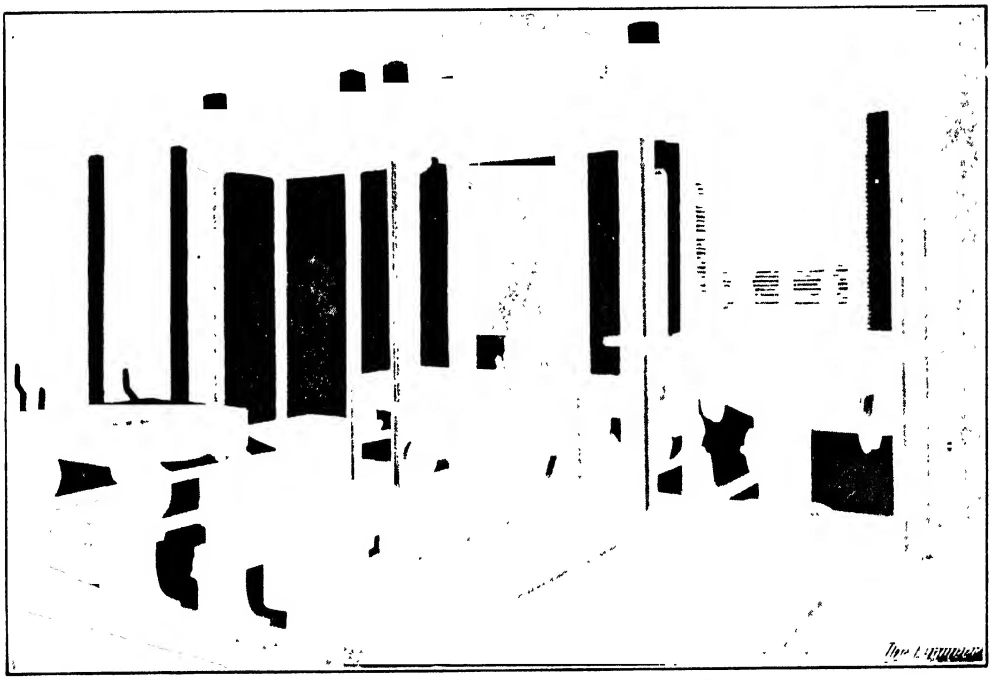


FIG. 69.—Stearine Presses for Demargarinating Oil.

The extraction of the " stearine " is an important operation, particularly in the case of cotton-seed oil. This oil, after being " demargarinated," is known as " winter oil," because it will not throw down a deposit or become cloudy at temperatures normally occurring in winter. A usual method of carrying out the demargarination is to cool the oil artificially until the " stearine " portions solidify, and then to pass the whole through a filter press. A slightly different method consists of completing the freezing of the whole oil in flat pans, wrapping the frozen cakes in bagging and pressing them in a hydraulic press. Under the pressure, the portions of the oil having the lowest freezing-point, liquefy, and are forced out and drain away. A set of stearine presses, suitable for this method of working, is illustrated in Fig. 69. The presses differ considerably from those of the Anglo-American type used for crushing seeds. Each is provided with a ram 12 in. in diameter and suitable for a working pressure of 2 tons. A square table is formed at the head of the ram, and on to this a four-wheeled carriage can be run on rails from either side of the press. The carriage is provided with catches,

which can be hinged down to engage the columns of the press, and with two vertical guide bars, which, when the ram rises, enter holes in the press head and so hold the carriage steady. The expressed oil is caught in the box-like carriages. There are two carriages for each press, so that one may be filled while the other is under pressure. Special provision is made to ensure that the pressure shall be applied very slowly. The refrigerated cakes are pressed between steel plates. These are sufficiently large to accommodate four cakes each.

All the machines and plant illustrated in this chapter represent the practice of Manlove, Alliott & Co., Ltd., Nottingham.

CHAPTER XIII

THE HYDROGENATION OR HARDENING OF OILS

Fatty vegetable and animals oils may be described as consisting of a glycerine part and an acid part. The composition of the glycerine part is constant. The composition of the acid part varies from oil to oil, and is characteristic of any one oil, or of any one group of oils.

Several important vegetable and animal oils contain an acid part having the general chemical formula $C_nH_{2n}O_2$. Among these we have butter fat, cocoa-nut oil, palm oil, palm kernel oil, lard, tallow, and various "butters," such as cocoa, mace and nutmeg butters. It will be noticed that the oils and fats mentioned are in general characterised by the possession of a thick consistency; that is to say, they have high melting-points, or, in other words, they are naturally "hard."

Many other important vegetable and animal oils differ from those just mentioned in that their acid parts fail to fit the general formula quoted to the extent of two, four, six or eight atoms of hydrogen. Thus, in rape oil, and certain fish oils, two hydrogen atoms are missing. Four are absent in the acid parts of soya-bean oil and cotton-seed oil. In linseed oil six atoms are missing, and in certain liver and blubber oils eight atoms are awanting. All these oils, it will be noticed, are in general characterised by the possession of a liquid consistency. In passing it should be observed that castor oil does not appear under either division. This oil is exceptional, for its acid part contains not two, but three atoms of oxygen.

The oils of the second division—or, to be quite exact, the acid parts of these oils—are termed unsaturated, for they are, theoretically at least, capable of taking up and combining with additional atoms of hydrogen. In practice, however, under normal conditions, hydrogen, even in the nascent state, is quite without action on fatty oils. The great commercial value attaching to the power of being able to convert an unsaturated into a saturated oil has led to much investigation of the matter. It has been discovered that the addition of the hydrogen atoms can be effected if the oil is suitably treated with hydrogen gas in the presence of finely divided nickel or palladium. Each of these metals acts as a catalyst, and is left unaltered after the hydrogen has been taken up by the oil.

These are the broad chemical aspects of the process we are now discussing. Wherein lies its commercial applicability? The answer to this question can be given in a general statement. For the purposes of modern industry the world's supply of natural fats is deficient, while the supply of liquid oils is superabundant. The hydrogenation process permits us to make good the deficiency by converting some of the superabundant liquid oils into hard fats.

As an instance of the commercial applicability of the hydrogenation process, we may look for a moment at the soap-making industry. The ideal substance for the soap maker to work with may be said to be tallow. It is a firm substance, and yields a firm soap such as we are accustomed to. Tallow, however, is expensive, and is obtainable only in strictly limited amounts. The soap maker accordingly falls back upon some of the harder oils, such as cocoa-nut oil, palm oil, and palm-kernel oil.

These oils are also expensive and are in increasing demand in other industries. If, however, the soap maker tries to replace them with one or other of the abundant naturally liquid oils, such as whale oil, soya-bean oil, and so on, his product loses greatly in quality, and is apt to be a soft, sticky mass, unusable or unsaleable as soap for many purposes. By hardening these oils before using them in the soap kettle, he obtains a substance practically identical with tallow without affecting the yield from them of that valuable by-product of the soap-making industry, glycerine. The hydrogenation process thus throws open to the soap maker a wide range of oils which otherwise would be next to useless for his purpose.

Similar remarks apply to the candle-making industry, which, again, calls largely for fats rather than oils. For certain edible productions, notably margarine and chocolate, fats are now in demand to a greater extent than can be conveniently met from natural sources of supply. Whatever may be the case to-day—it is very difficult to find out exactly how matters do stand at present—it is certain that artificially hardened oils will soon be in extensive and acknowledged use for edible purposes. Just for the moment there is a feeling of uncertainty as to this employment of them, for it is not yet settled how far the possible presence in the hardened oils of a small amount of the nickel or other catalyst is harmful to the human constitution.

The chief oil hardened at present is whale oil. Increasing quantities of cotton-seed, linseed, soya-bean, cocoa-nut, and other oils are, however, also being subjected to the process, so that the subject is one quite properly falling within the scope of this volume. With regard to the hardening of cocoa-nut oil, a word of explanation is no doubt desirable. This oil is just on the border line between the true oils and the true fats. It is one thing in one part of the world, and the other in another part. All its acid part is not saturated, but contains portions of unsaturated acids. It is therefore capable of absorbing a certain amount of hydrogen, and so becoming harder than it is normally in this climate.

Hardened oils are white, tasteless, odourless, substances of tallow-like consistency. Theoretically at least, they should all be identical, whatever may be the particular oil started with, and in practice such identity seems to be attained, at least in the oil as freshly hardened, but there is some uncertainty whether a hardened oil if kept long enough will or will not develop some characteristics of its parent. Thus, hardened whale oil may, sooner or later, develop a fishy smell, and hardened cocoa-nut oil the characteristic smell of cocoa-nuts. In practice, however, the oils are usually hardened at the soap works, or wherever else they are to be used, or are otherwise employed with but little interval between being hardened and being treated in industrial processes. The point is of importance, for there are distinct signs that, in the near future, certain oils will be hardened before shipment to this country. Thus the process is attracting considerable attention from the soya-bean oil producers in Japan and Manchuria, the idea being that hardened oils may be shipped and carried without risking that loss through leakage, etc., which is a serious item in the shipment of liquid oils.

The Technology of Oil Hardening.

Coming to the technology of the process we find that success is dependent primarily upon two circumstances, first, the careful preparation of the catalyst, and, secondly, the use of very pure hydrogen. Very little variation of procedure may quite readily result in an entire failure to harden the oil.

The catalyst commonly used on a commercial scale is metallic nickel prepared in a finely-divided state by chemical precipitation. Once made it must be kept

rigorously apart from certain other substances, notably air, moisture, sulphur, arsenic, carbon monoxide, methane, etc. These substances oxidise or otherwise react on the metallic nickel, and quite destroy its catalytic action. Thus it is stated that a tenth of 1 per cent. of sulphuretted hydrogen, if present in the hydrogen used in the process, will prevent the hydrogenation of the oil.

The effect of these substances on the catalyst is felt in three directions. First, as we have said, it means that the hydrogen used must be very pure, and free especially from moisture and sulphur compounds. Secondly, the oil to be hardened must be thoroughly freed as a preliminary from the moisture which, when received, it is certain always to contain. Thirdly, in preparing the catalyst a stage is reached when it must be treated and handled out of contact with the atmosphere.

Given the satisfactory attainment of these conditions the process is simple. The oil with the catalyst added is heated in an atmosphere of hydrogen inside a closed vessel—an autoclave—fitted with a mechanical agitator. The oil and hydrogen are brought into intimate contact and at the end of three to four hours the absorption is found to be complete. The temperature at which the work is carried on is of great importance. It appears that for any given pressure of hydrogen inside the autoclave there is a definite temperature which must be reached before the absorption begins. At atmospheric pressure this temperature appears to be about 250° C. In practice such a temperature would almost certainly result in the hardened oil being discoloured. To avoid this some temperature approximating 200° must be used. The pressure of the hydrogen has to be increased above atmospheric as the temperature is decreased. A normal working condition is a temperature of 170° to 180° C. in conjunction with a pressure of 70 to 80 lb. per square inch.

When the absorption is complete the oil is run out of the autoclave, cooled, filtered, and allowed to solidify.

For the purpose of this and the succeeding chapter we have made a close study of the hydrogenation and hydrogen-producing plants designed and patented by Mr. Howard Lane, of the Laboratory, Ashford, Middlesex. Mr. Lane has kindly allowed us to inspect when at work the experimental plants which he has erected at his laboratory. To avoid creating a misapprehension we desire to make it quite clear at this point that we are not dealing with a system or plant which is only in the experimental stage. The generation of pure hydrogen is a subject which has engaged Mr. Lane's attention since 1903. The development of his oil-hardening plant followed upon the commercial success of his ideas as to the generation of hydrogen. Many installations, both of the hydrogen plant and the hydrogenation plant erected to his designs, are to-day successfully at work on a large scale both in this country and abroad. It is proposed in this chapter to describe a typical hydrogenation plant on the Lane system, and in the next—because of the vital importance to the success of the hardening process of an inexpensive supply of pure hydrogen—to describe the Lane system of generating hydrogen.

In the engraving (Fig. 70), we reproduce the general plan of an oil-hydrogenising plant erected to Mr. Lane's designs. As set to work in the first instance, this factory has a capacity for treating 1 ton of oil per hour, but throughout provision is made for trebling the plant and the output. In this chapter we are concerned solely with the lower portion of the plan—the oil treatment department. The upper portion—more than 50 per cent. of the whole—represents the lay-out of the hydrogen-producing plant which we will deal with in our next chapter.

Reception and Desiccation of the Raw Oil.

The raw oil is received at the works at the point marked A in the lower left-hand corner of the plan. The first operation is to remove the oil in a cleanly and thorough manner from the barrels and to pass it into steel storage tanks. As the raw oil may be naturally thick—such as is the case if cocoa-nut, palm, or palm-kernel oil is being treated—means have to be provided for heating it so that the barrels may be properly emptied and the oil in the storage tanks may be kept sufficiently liquid to be pumped on to the next stage. The means provided consist of steam jets for heating the barrels and flat steam coils at the bottom of the tanks to preserve the contents in a liquid state. The tops of the storage tanks are open, and across their mouths is erected a wooden stage in which grilles are formed on to which the barrels are emptied.

The next stage consists in thoroughly drying the oil so as to meet the requirement for success, mentioned above, that the catalyst should not be brought at any time into contact with moisture. The desiccation is performed in two stages. The oil is first pumped from the storage tanks into open preliminary heating vessels circular in section and having conical bases. These vessels are fitted with mechanical agitating gear and with steam heating coils. In them the oil is freed of the greater part of its moisture. To secure the final and complete desiccation the oil is pumped into vacuum pans consisting of circular sectioned vessels with domed tops and conical bases, and containing a heating coil and mechanical stirring gear. The domed top of each pan is provided with an inlet connection for the oil and a connection to a vacuum pump. The outlet for the oil is through a cock at the foot of the conical base. Steam, fluid level and vacuum gauges, and thermometers are fitted in connection with the pans. The oil leaving the pans is now ready to be brought into contact with the hydrogen in the autoclaves, but before proceeding to describe these we will deal with the preparation of the catalyst.

Preparation of the Catalyst.

The catalyst employed in the Lane process is finely divided metallic nickel. It is received at the works in the form of nickel sulphate in crystals. The first step in its preparation consists of making a solution of the nickel sulphate and another solution of sodium carbonate. This is done in the two tanks B, C, respectively. Each of these tanks is fitted with an open steam jet to facilitate the preparation of the solution. They are erected over a third tank provided with means for mixing the two solutions when they are turned into it. The result of this mixture is the precipitation of insoluble nickel carbonate and the passage of sodium sulphate into solution. Previous to the admission of the two solutions a quantity of finely divided refractory neutral material is placed in the mixing tank. In practice this material is usually kieselguhr—that is to say, infusorial earth consisting of siliceous diatom fossils. Its function is to act as a carrier for the nickel.

The mother liquor, the precipitate of nickel carbonate, and the kieselguhr are drawn off from the mixing tank and pumped through a filter press of the type described in our preceding chapter. When the filtering is completed the nickel carbonate and the kieselguhr are found consolidated on the filter cloths as cakes. These cakes are thoroughly dried in hot-air stoves, and thereafter are reduced to powder by means of an edge runner. The carbonate has now to be roasted or calcined so as to reduce it to the form of oxide. Thereafter comes the very delicate operation of reducing the oxide to the metallic form. This is effected by heating the oxide in contact with hydrogen—which must be quite free from air—at a certain temperature. One form

of the apparatus employed is contained within a heat-insulated vertical case to which the pulverised material is fed automatically at the top, while the hydrogen is admitted at the foot. Inside the case there is provided a series of slowly reciprocating grids or sieves. The movement of these constantly exposes fresh portions of the substance to the action of the hydrogen, and at the same time determines the rate at which the substance falls through the case. The apparatus is heated by the hydrogen itself, the gas before its admission being heated to the requisite temperature in an external superheater or stove. In this particular form of reducing apparatus the reduction of the oxide to the metallic form is effected in the lower portions of the case. In the upper portion the material—fed to the case in the form of the carbonate—is calcined to the oxide. After leaving the lowest grid the reduced material accompanied by the kieselguhr, must not, of course, be permitted to come into contact with the air. It is therefore caused to fall into a tank of oil of the same kind and quality as that to be hardened. After thorough mixing the black oily preparation is ground to a suitable consistency, and is then finally ready for admission to the autoclave along with the oil.

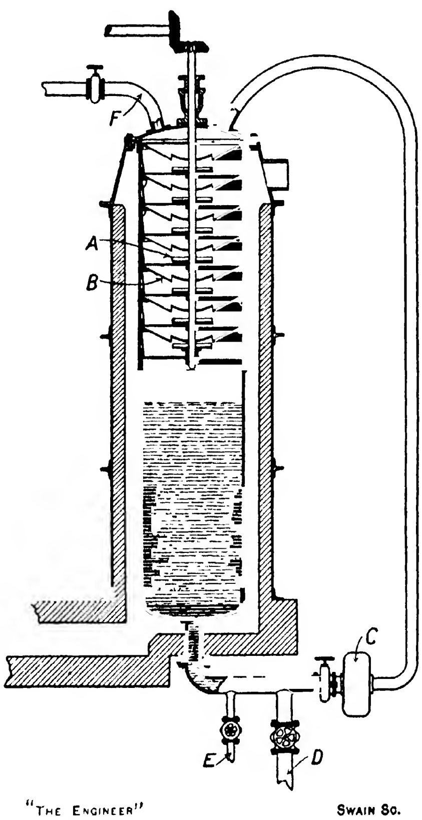


Fig. 71.—Lane Autoclave.

The Lane Autoclave.

An autoclave, designed according to Mr. Lane's patents, is illustrated in section in Fig. 71. It is a cylindrical upright vessel, closed top and bottom, and surrounded by an outer jacket of fire-brick to constitute a flue for the gases of a separately fired furnace. The upper half of the vessel is occupied by agitating gear consisting of a series of square beater discs A mounted on a power-driven vertical shaft, and an equal number of metal plate cones B formed with square holes at their centres, and fixed relatively to the walls of the vessel. The lower half is, in the working condition, occupied by the oil to be treated mixed with the catalyst. A pump C draws the oil from the foot of the vessel and discharges it continuously on to the uppermost of the cones B. Falling from this on to the first of the beater plates A it is shot off against the walls of the vessel, and is discharged through the opening in the second cone on to the second beater plate. Before it returns to the bottom half of the vessel the oil is thus thoroughly churned up in the atmosphere of hydrogen under pressure which fills the upper half of the vessel. The oil and catalyst are introduced at D and the hydrogen at E. At F a connection to a vacuum pump is provided whereby, as a preliminary to the introduction of the catalyst and hydrogen, the air in the vessel can be removed.

It has been found, as the result of practical experience, that the oil in the lower part of the vessel is apt to suffer from being exposed too long in contact with the hot

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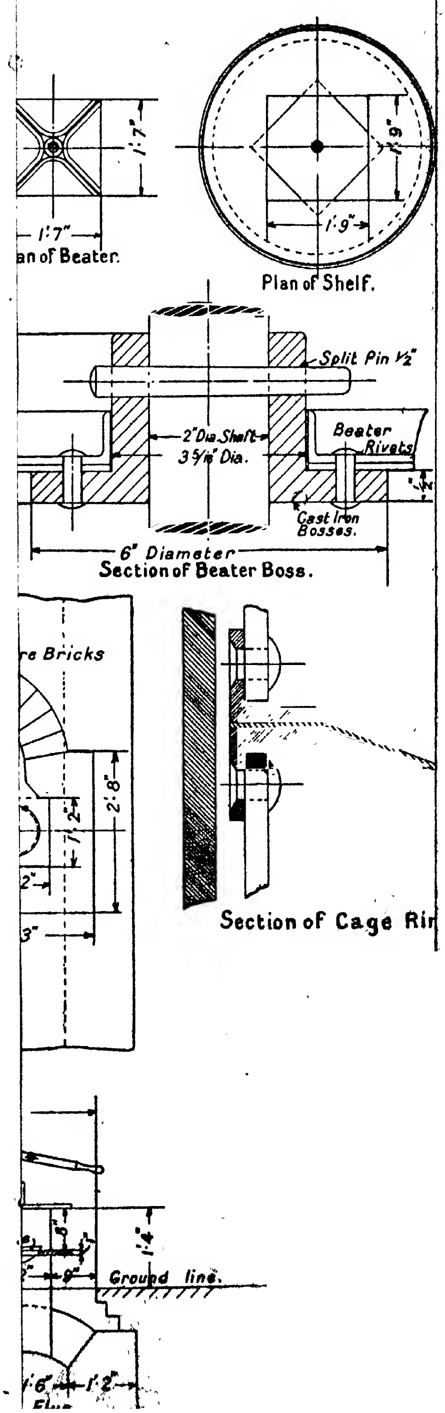


surrounding walls. To overcome this Mr. Lane, in his most recent designs, extends the agitator shaft to the foot of the vessel, provides it with a beater or paddle, and surrounds it with a cylindrical jacket. The oil is thus circulated from the paddle up the annular space between the jacket and the walls of the autoclave, and down again through the jacket to the paddle. In Plate VI. we give the general arrangement drawing of a Lane autoclave provided with this improvement.

If matters are properly regulated the pressure inside the autoclave, as the hydrogen is pumped in, is seen to rise at first. On reaching a certain point, depending upon

FIG. 72.—Mr. Howard Lane's Experimental Oil-Hardening Plant.

the temperature maintained in the oil, the pressure becomes stationary, indicating that the hydrogen is being absorbed by the oil as fast as it is pumped in. When, by sampling, the hardening is judged to be completed, the oil is drawn from the autoclave through the pipe D (Fig. 71), and, as indicated on the engraving (Fig. 70), is cooled and filtered. The cooling is not sufficient to solidify the oil, but is only sufficient to prevent the hot oil from ruining the cloths of the filter press. In the filters the very large bulk, if not the whole, of the metallic nickel and the kieselguhr is held back. The cakes left on the cloth are washed and freed from oil, are broken up, and are returned to the catalyst preparing department, where the material is made ready for further use.

In Fig. 72 we give a view showing the interior of Mr. Lane's laboratory at Ashford with the experimental oil-hydrogenising plant. In the middle of the background the autoclave is to be seen with, to the right, the coke or coal-fired furnace used in

conjunction with it. In the foreground to the right we have the cooler for the hardened oil, and to the left the filter press.

Cost of Working the Process.

The following estimate of the cost of working a plant having a capacity of 1 ton of oil per hour is based on figures supplied by Mr. Lane. In studying the figures it should be noted that the rates charged for nickel sulphate, kieselguhr, and carbonate of soda are not necessarily those for which these materials could be bought in the present abnormal time. On the other hand, the price set against the hydrogen is, owing to recent improvements, probably in excess of that at which it is obtainable, even under the conditions of to-day. In the second place it is to be noticed that the figures relate to the hardening of linseed oil. Certain oils, for example, whale oil, require more hydrogen to harden them than does linseed. Others, such as cotton-seed oil, require less. As the charge for hydrogen is the heaviest in the list, the question of what precise oil is being dealt with is a point of considerable importance in its bearing upon the working costs. The only other heavy item in the list is that set against "loss of catalyst." The magnitude of this figure also depends upon the nature of the oil being hardened.

Cost of Hardening 1 Ton of Linseed Oil.

	£	s.	d
Hydrogen: 3,530 cu. ft. at 4s. 6½d. per 1,000 cu. ft.	0	16	0
Loss of catalyst	0	14	2
Fuel for Heating: 1 cwt. coke at 30s. per ton	0	1	6
Power	0	1	0
Steam: 1,344 lb. at 3s. 4d. per ton	0	2	0
Water: 400 cu. ft. at 10d. per 1,000 cu. ft.	0	0	4
Filter cloths: 1 yard at 1s. 3d. per yard	0	1	3
Labour (including preparation of catalyst): 7 men at 6d. per hour	0	3	6
Running repairs	0	2	0
Total	2	1	9

Nickel sulphate at 42s. per cwt., kieselguhr at 17s. per cwt., carbonate of soda at 55s. per ton.

CHAPTER XIV

THE GENERATION OF HYDROGEN FOR OIL HARDENING PURPOSES

So important to the successful working of the hydrogenation process of hardening oils is an inexpensive commercial method of obtaining pure hydrogen that we need make no excuse for devoting a separate chapter to the subject. There are, of course, various methods of generating hydrogen on a commercial scale, one well-known one being the Linde-Frank-Caro process, which extracts the hydrogen from water gas by liquefying the nitrogen, carbon monoxide, etc., in a liquid air condenser. This process is worked in this country by the British Oxygen Co., Ltd., and, we understand, yields a gas which is suitable for hydrogenating oils.

The process we propose here to deal with exclusively is, as we mentioned in our preceding chapter, that which has been developed within the past fourteen years by Mr. Howard Lane, of the Laboratory, Ashford, Middlesex. The basis of this process is the oxidation of metallic iron by means of steam, the oxygen of the steam entering into union with the iron, and the hydrogen being set free. Proposals on this basis have been numerous—probably more numerous than those under any other system of producing hydrogen—but in many instances success with the method has been confined to the laboratory. The undoubted commercial success which Mr. Lane has achieved with the process is due very largely, but not, as we will have to explain, wholly, to the attention which he has given to the design of the details of the plant used.

The iron, under the Lane system, initially supplied to the hydrogen retorts is calcined spathic iron ore, the purest form in which ferrous carbonate, $FeCO_3$ occurs in Nature. This substance, when subjected to heat, speedily parts with its carbon dioxide, and becomes converted to a porous mass of ferrous oxide, FeO. So converted it is packed within the hydrogen retorts. The working of the process calls for the alternate reduction of the ferrous oxide to metallic iron by means of a combustible gas, and the conversion of this metallic iron back to ferrous oxide by means of steam. The combustible gas used for the reduction may in a small plant be ordinary town's gas, but on a large scale purified water-gas, generated at the site, is undoubtedly to be preferred on the score of economy. When water-gas is used it is purified by the removal of the sulphur dioxide, hydrogen sulphide, carbon dioxide, moisture, and other impurities, which, as made in the producer, it contains. As admitted to the ferrous oxide in the hydrogen retorts, it therefore consists of about equal quantities of hydrogen and carbon monoxide. The reduction of the ferrous oxide to metallic iron is accomplished at the expense of these two constituents, which are converted respectively into moisture and carbon dioxide. The reduction being complete, the supply of purified water-gas is shut off and steam at a low pressure is admitted to the retorts. The earlier portions of the hydrogen, which immediately starts to come off, are sent elsewhere than to the hydrogen holder, for they are impure to the extent that they carry with them the reducing gas, the water vapour, and the carbon dioxide, lingering in the retorts as a result of the previous reduction process.

Three practical points must now be noted, for they lie at the basis of Mr. Lane's method of working. In the first place, it has been found that the reduction of the

material in the retorts occupies about twice as long as the oxidation. Accordingly Mr. Lane divides his retorts into three sections, two of which are "reducing," while one is "oxidising." In the experimental plant at Ashford we found that the control valves were being operated every ten minutes, so that each section of the retorts was producing hydrogen for ten minutes in every half hour.

In the second place, Mr. Lane has found a difficulty which previous workers with this process have also met, and which has been responsible for its being commercially impracticable, or for its being deemed so, in more than one instance. The difficulty is that, after a time, the iron gradually loses its activity, and in the end practically fails to react with the oxygen of the steam. The trouble, Mr. Lane has discovered, arises from the fact that it is not possible entirely to free the water-gas, or other reducing gas used, from sulphur, carbon dioxide, and other impurities. These impurities either combine with the iron or collect within its pores, so reducing and finally stopping, its activity. To overcome this Mr. Lane arranges that, at stated intervals, the working of the retorts is interrupted momentarily while air is passed through them backwards. This burns out, or otherwise removes, the impurities collected in the iron.

Thirdly, the water-gas, or other reducing gas, it has been found, must considerably exceed in amount that theoretically necessary to effect the reduction of the iron oxide in the retorts. The gas leaving the retorts during the reduction period is thus unaltered water-gas, carrying with it the moisture and carbon dioxide resulting from the oxidation of a portion of the volume entering the retorts. This gas would represent a considerable loss but for the fact that, after removing the moisture in it, it may be deflected and used for firing the retorts.

In Fig. 70 (Chapter XIII.) the general arrangement is given of the hydrogen-generating plant attached to an oil-hydrogenising factory erected to Mr. Lane's designs.

The plant consists of three principal items, namely, (*a*) a hydrogen retort furnace containing the iron-working substance which is alternately oxidised by the steam delivered from (*b*) a boiler, and reduced by the products delivered from (*c*) a water-gas generator. Added to these there are (*d*) purifiers for the water-gas, and for the hydrogen (*e*) holders for the two gases, (*f*) compressors for the hydrogen, and (*g*) reservoirs for the storage of the compressed hydrogen.

Water-gas Generators and Purifiers.

It is, we think, unnecessary for us here to enter into a description of the water-gas generators supplied with the plant. Although they embody in their design certain details representing improvements of Mr. Lane's own invention, they are in principle, and in action, similar to all other water-gas generators. Further than this they do not form an essential feature of the plant, for other combustible gases—for example, town gas—can, as we have remarked, take the place of water-gas. It is sufficient for us to say that the generators are supplied with air from a turbine-driven blower, and with steam from the same boiler as that supplying steam to the hydrogen retorts. The water-gas generated has, on the average, a calorific value of from 280 to 300 B.Th.U.'s, and in the raw state may be said to have roughly the following composition :—Hydrogen, 49 per cent. ; carbon monoxide, 43 ; methane, $\frac{1}{2}$; carbon dioxide, 4 ; together with nitrogen, sulphur dioxide, hydrogen sulphide, moisture, and dust and other mechanical impurities. The gas, on leaving the generators, passes through a superheater, where it exchanges some of its heat with the steam flowing from the boiler to the generators. Thereafter it is led to a scrubber, where it is cooled and washed with water to deprive it of its dust. It is then taken to a gasholder.

The gas as required is withdrawn from the holder by means of a "booster" or

compressor and passed along to the purifiers. The booster is driven by a small steam engine, which is controlled by the pressure of the gas in such a way, that as the resistance of the purifiers increases so does the pressure of the gas. A by-pass is provided in order that the gas may be sent, if necessary, straight to the purifiers at the gasholder pressure. This is sometimes convenient, as, for example, when the booster has to be cleaned or repaired or when the hydrogen retorts are being run banked.

The water-gas purifiers for the installation represented in Fig. 70 are four in number. They serve in the usual way to remove the sulphur dioxide, hydrogen sulphide, carbon dioxide, moisture, etc., from the water-gas. They are controlled by a centre valve of special construction, packed with hard fat, to prevent leakage, on the principle of the Stauffer grease cup. This valve is actuated in such a way that one of the purifiers is always in reserve, while the gas passes in sequence through each of the remaining three. The crudest gas always enters the foulest purifier, and leaves from the cleanest. At intervals, the foulest producer is switched off for cleaning and recharging, while the stand-by purifier is brought into action at the other end. In this way all four purifiers are cut out and cleaned in turn without interfering with the continuous purification of the water-gas. The gas, after leaving the purifiers, is ready to be passed into the hydrogen retorts.

Hydrogen Retort Furnaces.

The general arrangement of the Lane hydrogen retort furnace is represented in the drawings given in Plate VII. Before describing the construction and mode of action of the furnace, we would repeat what we remarked above, namely, that it takes twice as long to reduce the ferrous oxide to metallic iron with the water-gas as to oxidise the iron with the steam. In other words, the time spent in preparing a given weight of material for the production of hydrogen is twice as great as the time occupied in the succeeding step during which the hydrogen is being generated.

The furnace consists, primarily, of a brickwork casing containing, in the size illustrated, thirty-six vertical, cast-iron, pipe-like retorts. The top ends of the retorts are flanged and provided with covers for removal when the retorts have to be recharged with ferrous material. The spent material is removed through similar covers at the foot of the retorts. The thirty-six retorts are arranged in two groups, each containing two rows of nine retorts each. This division is of no practical significance. What is, however, important is the division of the thirty-six retorts into three groups P, Q, R, each group containing three of the retorts in each longitudinal row. While the groups P and Q are "reducing," the group R is "oxidising." After running thus for a certain length of time, the group Q is changed over to "oxidising" and the group R to "reducing," the group P remaining at the reducing setting. Thereafter P is set to oxidise, and Q and R to reduce. In this way the generation of hydrogen—from the oxidising group—is made continuous, while the double time required for reducing is allowed to each group.

In order to facilitate our description, the three groups of retorts are, in the diagram of the plant given in Fig. 73, represented as three single retorts P, Q, R. Across the front of the furnace and external to the brickwork, there run six horizontal pipes A, B, C, D, E, F. The top end of the retort P is connected as at G to a valve H on the pipe A, and the bottom of the same retort as at J to a valve K on the pipe F. The top and bottom ends of the retort Q are similarly connected to valves on the pipes B, E, respectively, and the top and bottom ends of the retort R to valves on the pipes C, D. The three pipes A, B, C are connected at each end to vertical pipes L, M, and

the three pipes D, E, F to two other vertical pipes N, S. The valves H, K are interconnected, so as to be operated together. The two other pairs are similarly connected.

The pipe N is connected with the water-gas supply. With the valve setting indicated in the diagram, the retorts P, Q are receiving water-gas from the left-hand portions of the pipes F, E respectively. The gas rising up the retorts is reducing the ferrous oxide in them, and with the moisture and carbon dioxide, resulting from the reaction, is passing away by the left-hand portions of the pipes A, B to the pipe L. From this pipe it may be sent wholly into the furnace for heating the retorts—no other fuel being necessary. As we have already said, it is not practicable to work

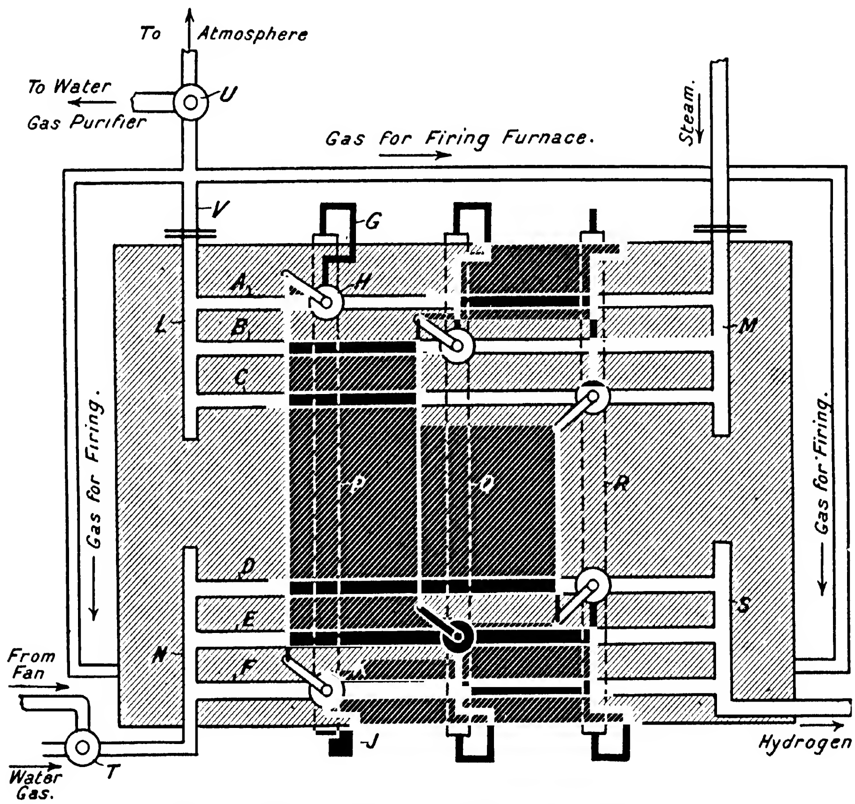


FIG. 73.—Diagram of the Lane Hydrogen Retort Furnace.

with just sufficient water-gas to reduce the charge of ferrous oxide in the retorts. An excess is required, but, as will now be understood, the excess amount in Mr. Lane's plant is subsequently usefully employed. At one time Mr. Lane utilised the excess gas passed through the retorts, partly for firing the furnace and partly by returning it to the reducing gas purifiers, as indicated in the diagram, so as to make it available for a second passage through the retorts. This plan has been given up, for it was found that the volume of carbon dioxide coming off with the excess gas was such as seriously to overtax the capacity of the purifiers. Mr. Lane now prefers to utilise the excess gas either wholly for firing purposes or partly for firing and partly for establishing a reducing envelope for the combustion chamber in which the retorts are set, the object being to minimise the wear of the brickwork.

The pipe M is connected with a supply of steam. With the valve setting represented in the diagram, the retort R is receiving steam from the right-hand portion of the pipe C. This steam passing downwards becomes decomposed, oxidising the metallic iron in the retort and setting free hydrogen. The hydrogen leaving the bottom of the retort reaches the right-hand portion of the pipe D and so passes into the pipe S, whence it is conducted to a purifying plant and a gasholder.

It will thus be seen that simply by the operation of two of the three connected pairs of valves, every ten minutes or so, the plant is capable of giving a practically continuous output of hydrogen gas. Two practical points have, however, to be noted. In the first place, when any one of the retorts is changed over from "reducing" to "oxidising," it is at the moment of the change filled with water-gas carrying a certain percentage of moisture and carbon dioxide. The first portion of hydrogen formed is therefore bound to be contaminated with these substances. To avoid passing this impure gas into the pipe S, it is arranged that the valves, while they can be operated simultaneously in pairs, as stated, can also be operated separately. Thus, when the reducing period in, say, the retort P is completed, the valve H is operated to admit steam to the top of the retort, while the valve K is for the moment left untouched. The steam being at a higher pressure than the water-gas, passes down the retort and becomes converted to hydrogen. This hydrogen mixing with the water-gas in the retort causes the latter to flow back into the pipe F and the pipe N. The impure hydrogen then passes with the fresh water-gas into the retort Q and the retort R—now set for reducing—and is therefore not wasted. In a very short time the hydrogen generated is sufficiently pure to permit the valve K to be operated so as to allow the retort P to take up its proper function.

When passing from "oxidising" to "reducing," the retort is at first filled with pure hydrogen. This, beyond representing a small waste, is of no significance, as the incoming water-gas will merely be enriched in hydrogen to a proportionate extent. The pair of valves can, therefore, be operated simultaneously when the change from oxidising to reducing is being made.

In the second place, as we have already said, the ferrous material, unless revivified in some way, very soon loses its activity and fails to decompose the steam. This phenomenon, Mr. Lane has found, is due to the deposition on the iron of sulphur and other impurities which, even with very careful purification of the water-gas, accumulate in the retorts during successive periods of reduction. The practical cure devised for the trouble is at intervals to blow air through the retorts, so as to burn out the accumulated impurities. To effect this, the three-way cock T, Fig. 73, is turned to shut down the supply of water-gas and to open a branch pipe leading from a fan or other blower. The three-way cock U on the excess water-gas outlet pipe is also turned so as to close this pipe and open a branch pipe leading to the atmosphere. The air from the fan, if the retort valves are placed in the "reducing" position, then passes up through the retorts, and with the sulphur dioxide and other products derived from the impurities in the ferrous material blows off into free space.

The action of the water-gas on the ferrous oxide during the reducing period results, as we have said, in the excess water-gas passing off being laden with moisture and contaminated with carbon dioxide. For efficient combustion that portion of the water-gas used for firing the furnace should not be heavily laden with moisture. Accordingly, somewhere at or near the point V (Fig. 73), the excess water-gas is taken off to a condenser and returned. The position of the condensers relatively to the furnaces is indicated in the plan given in Fig. 70.

With a little study of the drawings given in Plate VII. the lines on which the

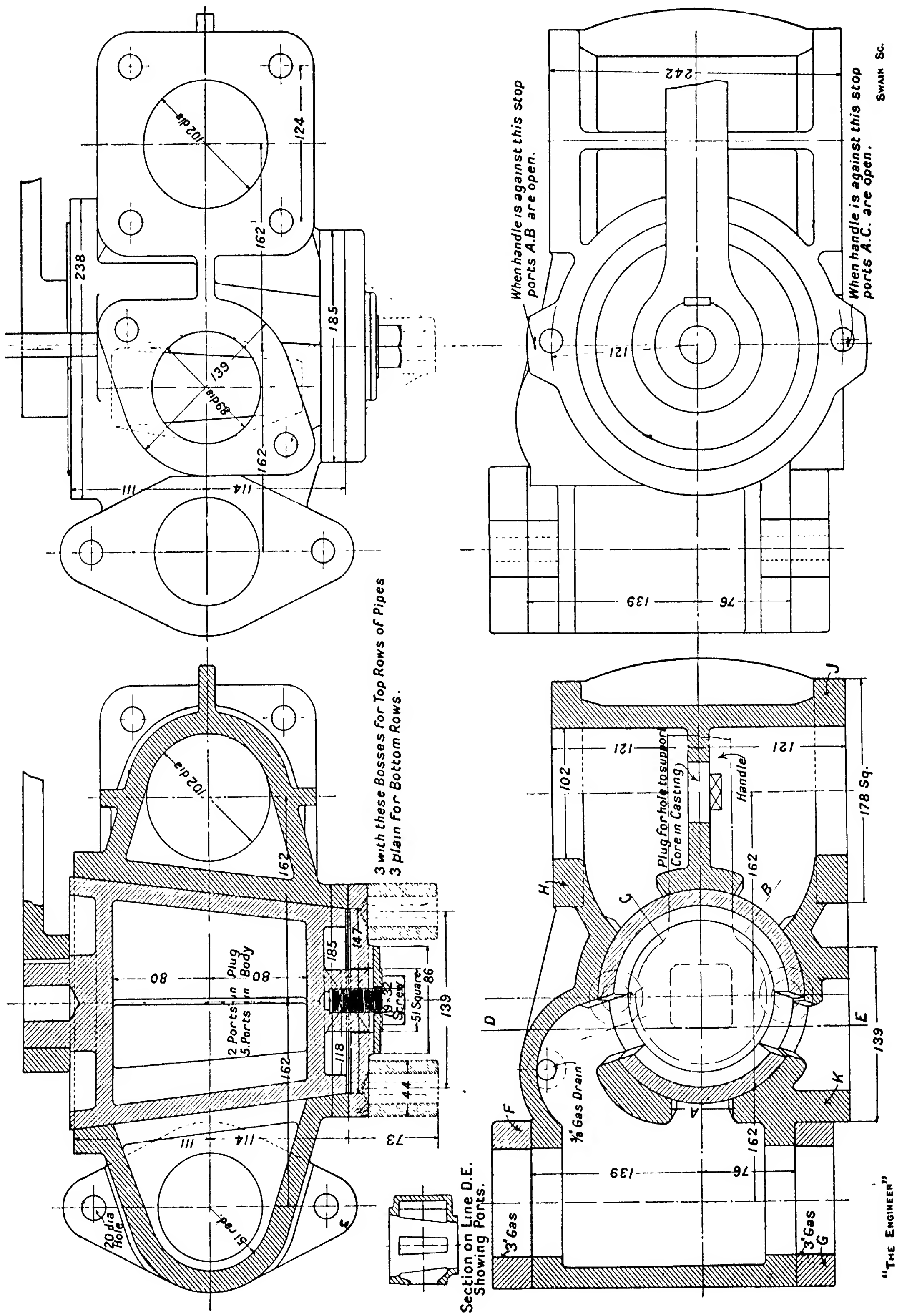


Fig. 74.—Three-way Reversing Cock for Hydrogen Retort Furnace.

design of the hydrogen retort furnace is carried out in practice will now readily be understood. Several points, however, may usefully be called attention to.

The retorts are of cast iron and are 9 in. in internal diameter, 1½ in. thick, and 9 ft. 9 in. long. Each fits into a base socket and seats therein on a joint of asbestos. The three groups of retorts P, Q, R, as shown in the plan, are each divided into two equal sub-groups. Six pipes—see the side elevation—run horizontally along the two sides of the furnace exterior. To each of these pipes the top—or the bottom—ends of a sub-group of the retorts are connected. Each of the six pipes on one side of the furnace is connected to the corresponding pipe on the other side by a horizontal pipe extending across the front of the furnace. This front pipe in each instance is interrupted at a suitable point to couple up with the two flanges F, G of the reversing cock—see Fig. 74. The top ends of the twelve retorts in each group are thus connected to one such reversing cock, while the bottom ends of the same twelve retorts are connected to a second reversing cock situated directly in line with and below the first, as shown in the front elevation in Plate VII. In front of the six front pipes referred to, and connected to the flanges H, J of the reversing cocks, lie the six pipes represented in the diagram Fig. 73, at AB—F. The vertical pipes L, M, N, S in the diagram are clearly shown in Plate VII., the only point to notice being that in practice the pipes L and M are respectively united to the pipes N and S, and are not separated therefrom. A blank, however, is interposed between the flanges of each pair.

With the cock plugs turned anticlockwise through about 30 degrees from the position shown in the plan, Fig. 74, the ports A and B are opened, and reducing gas is sent upwards through the retorts. A 60-degree movement of the plug in the clockwise direction from this position opens the ports A, C, and causes steam to pass downwards through the retorts. It will be noticed that a fourth and fifth port are formed in the body of the reversing cock, and that when the cock is in the central position shown in the engraving these two ports are open to one another. The flange K in each of the three lower reversing cocks is open to the atmosphere. In the three upper cocks it is connected by a vertical pipe to a horizontal pipe extending across the top front edge of the furnace casing. At one end of this horizontal pipe an ejector is fitted. By turning the reversing cocks into the central position, and setting the ejector to work, air is drawn upwards through the retorts for the purpose of burning out the impurities which, in time, accumulate on the ferrous material. The use of an ejector in this way instead of a fan, as indicated in Fig. 73, has certain obvious advantages, and is now Mr. Lane's standard practice.

It will be noticed from the front elevation in Plate VII. that the spindles of the three upper reversing cocks are extended down to the level of the lower cocks so that the handles of each pair are brought close together. The two cocks of each pair can thus be moved simultaneously as when passing from "oxidising" to "reducing," or separately as when the impure hydrogen has to be blown momentarily into the water-gas pipes at the commencement of the oxidising periods.

During the normal running of the furnace the excess water-gas is, as we have said, made use of in part for firing the retorts. At the commencement of a run a valve near the reducing gas inlet is closed and another one on the same pipe is opened. This enables the furnace to be fired with water-gas taken direct from the supply main. These means are also called into use during the slack periods, when the generation of hydrogen is interrupted. The firing may be reduced during such periods, but it is not desirable that it should be totally stopped. Generally Mr. Lane recommends that the plant should be run continuously day and night; but if this is impracticable, he recommends that the temperature of the furnace should be

kept as nearly equal as possible, for this reduces the wear and tear on the furnace work.

The plant illustrated in Plate VII. gives an output of about 3,500 cub. ft. of hydrogen per hour. For smaller plants having hourly outputs of, say, 250 to 1,000 cub. ft. ordinary town's gas is conveniently used for reducing the ferrous material and for firing the retorts. The small experimental plant at Mr. Lane's laboratory—see Fig. 75—is operated in this manner. But for plants above such outputs up to the largest size—say, 10,000 cub. ft. per hour—it is distinctly economical to install with them their own gas producers. The purity of the gas generated by Mr. Lane's process is guaranteed by him to be from 99 to 99½ per cent. In practice, however, this, we are informed, is exceeded, the purity reaching as high as 99¾ per cent. The purification of the hydrogen after it leaves the retorts consists of passing it through a scrubber,

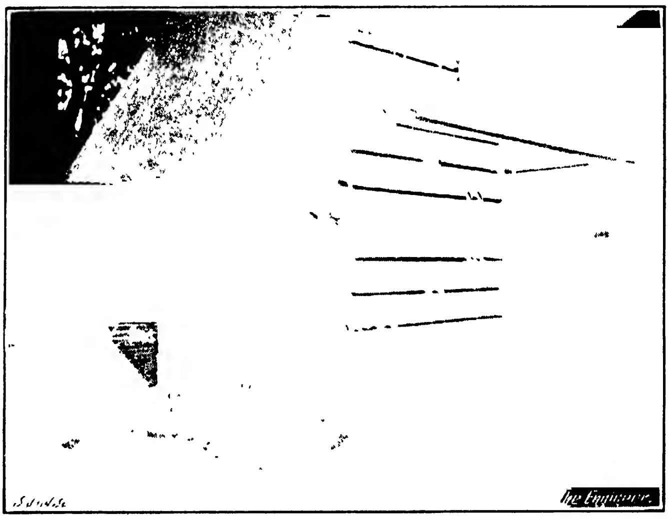


FIG. 75.—Experimental Hydrogen Plant.

where it is washed with water, and then through purifiers in which lime is employed to remove minute traces of such impurities as sulphur. After purification the gas is passed into a holder, whence it is withdrawn as required, compressed to a pressure of anything up to 3,000 lb. per square inch, and stored in a battery of weldles steel cylinders. From these it is allowed to expand at the proper pressure into the oil hydrogenising autoclaves.

The cost of producing hydrogen by this method is difficult to state, for it depends almost entirely upon the local prices of fuel and labour. It may, under normal conditions, be expected in the average case to vary from 3*s*. 6*d*. to 7*s*. 6*d*. per 1,000 cub. ft. In some cases, however, it may be as low as 2*s*. 6*d*., or less actually than the cost of town's gas in the London area.

Before leaving this account of Mr. Lane s apparatus, it may perhaps be stated that his oil hydrogenating plant was the outcome of the success which attended his efforts to produce pure hydrogen in large quantities under commercial conditions. It would appear likely that in the near future Mr. Lane's hydrogenising plan' may be applied to substances other than the classes of oil named. A very promising, and, if

successful, a very important application of it, lies in its use for hydrogenising mineral oils. It may yet be possible to synthetise petrol by its means. Mr. Lane has already succeeded in devising apparatus whereby he can cause hydrogen to combine with acetylene, C_2H_2; to produce ethylene, C_2H_4, a gas which can be liquefied at a temperature of 0° C. by a pressure of 41 atmospheres, and which possesses great energy as a motive-power fuel.

CHAPTER XV

THE MANUFACTURE OF SOAP

SOAP-MAKING provides a very important industrial outlet for the employment of vegetable oils, although, of course, the soap maker also uses large quantities of animal oils and fats.

CHEMISTRY OF SOAP-MAKING.

As we remarked in a preceding chapter, fatty vegetable and animal oils may be considered as consisting essentially of a glycerine part and an acid part. To the soap maker the acid part is the portion of prime importance. In the process of manufacture the acid part is caused to unite with an alkali, the glycerine part being in general left over as a by-product. It is, of course, a very valuable by-product, particularly at the present moment, and, as a consequence, we find it an increasingly common practice, particularly on the Continent, to recover the glycerine from the oil by special processes in deglycerinising works, which carry on their industry quite apart from that of the soap maker. Under these conditions the soap maker works with the by-product of another industry, namely, the fatty acid stock discarded from the deglycerinising works. With the plant employed in the latter works we do not propose in this chapter to deal. Our attention will be devoted solely to the manufacture of soap from undivided oils and fats.

When an acid (say, sulphuric acid) is caused to act on a metal (say, copper) a salt (copper sulphate) is produced. If the acid is the fatty acid contained in a vegetable or animal oil or fat, and if the metal is either sodium or potassium, the salt produced is known as a soap, a hard soap if sodium is the metal and a soft soap if it is potassium. Other soaps are possible and are made. Thus practical uses are found for soaps obtained by substituting for the alkali metals either iron, nickel, cobalt, zinc, magnesium, aluminium, copper or mercury. These "soaps" are, in general, insoluble in water, and are used for such purposes as waterproofing agents for canvas, as "driers" to be added to boiled oil or varnish, as constituents of anti-fouling compositions for ship bottoms and so on. We need say nothing more about the manufacture of these "soaps" than that they are made similarly to ordinary soap, or by employing such soap as a basis for decomposition.

Pure hard soap is thus the fatty acid salt of the metal sodium. It should be perfectly neutral. It contains none of the glycerine of the oil or fat from which it was formed. Pure soft soap is the neutral fatty acid salt of the metal potassium. In its commercial production, practice is divided as to whether or not it should be freed from the glycerine of the oil or fat used in its manufacture. It seems to be established that if the glycerine is removed the quality and appearance of the soap suffer, and accordingly it is quite a common practice to allow the glycerine to remain in the soap.

SOAP BOILING.

There are two distinct methods of making hard or soda soap, namely, the hot and the cold processes. The latter has a restricted application, and is not of sufficient

importance to be considered here. Under the hot process the sodium is presented to the fatty acid of the oil or fat in the form of an aqueous solution of caustic soda, NaOH. This solution is added gradually to the oil or fat in a soap kettle, the whole being kept boiling. A typical soap kettle, made by W. J. Fraser & Co., Ltd., of Dagenham, Romford, Essex, is illustrated in Fig. 76. It is built up of mild steel plates, and contains several separate steam heating coils and a swivelling outlet pipe with a chain hoist, whereby the soap, when formed, may be drained off. At the foot of the kettle an outlet is provided for the liquor separated from the soap. The size of these kettles may vary from 8 ft. diameter by 8 ft. deep to 13 ft. diameter by 14 ft. deep, and their capacity from 5 to 25 tons. The boiling, it will be seen, is carried out at atmospheric pressure. This is the common practice. A recent improvement consists in conducting the operation under about 100 lb. of pressure in a closed vessel some 4 ft. in diameter by 8 ft. high.

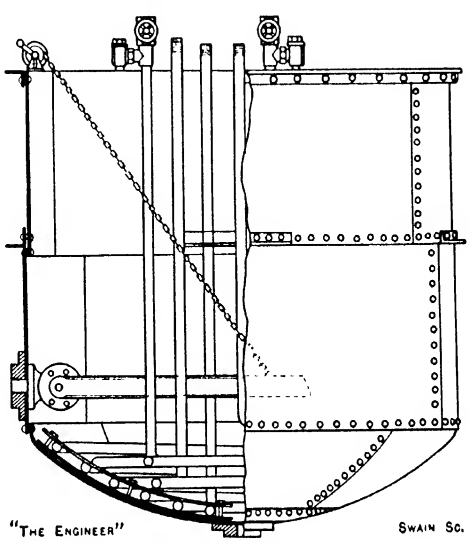


Fig. 76.—Soap Kettle—Fraser.

The soda solution is added gradually to the oil or molten fat in the kettle. If it is added too rapidly the saponification process is retarded. On the other hand, the total amount of soda solution mixed with the oil or fat must be more than the quantity theoretically necessary completely to saponify the substance. An excess is required, because if the theoretical amount only is used a point is reached at which the soap formed up to that point, the oil or fat yet remaining to be saponified and the alkaline solution corresponding to this quantity of oil or fat will establish a balance.

When the boiling operation is completed, the kettle contains, first, soap, and secondly, water, in which are dissolved the surplus caustic soda and the glycerine set free from the oil or fat. Various impurities from the caustic soda and some animal or vegetable tissue or other non-saponifiable matter from the oil or fat used will also be present. The mass in the kettle, for the moment, is a more or less clear homogeneous substance. Soap, however, is scarcely, if at all, soluble in a solution of salt. Accordingly, dry common salt is shovelled into the kettle, and the whole contents are thoroughly boiled up again. The salt entering into solution causes the soap on cooling to separate out on the surface. The aqueous liquor below the soap containing caustic soda, salt and glycerine in solution is run off through the bottom of the kettle and sent to the glycerine recovery department. The soap layer is now boiled up again with water and again salted out. The aqueous liquor is run off and the boiling and salting process repeated a third time. Thereafter, the soap left when the third liquor is drained off is given a final boiling with water in order to hydrate it to the correct degree. It is not, however, subsequently salted, but is allowed to stand for some few days undisturbed. At the end of this time it is found to have separated into three layers. At the foot there is a small layer of alkaline liquid. Intermediately, and amounting to about a third of the whole mass in the kettle is a layer of dark-coloured soap called the "nigre." This substance contains traces of caustic soda and

salt solution, and owes its dark colour to the presence in it of soaps of iron, copper. and other metals. Above this is the " neat " soap which, being practically pure and neutral, is in a condition to be used. The " nigre," after removal, is boiled and salted and otherwise treated for the recovery of its valuable portions.

Crutching.

The " neat " soap is, as we have said, in a condition to be used. In nearly every case, however, it is passed into a " crutching " machine, wherein colouring, scenting or other matter is added to it. Among such other matter are various " fillers," such as clay, talcum, chalk, barytes, seed husks, asbestos, magnesium salts, and starch. These substances increase the weight of the soap, and are frequently regarded as adulterants. In some cases the soap is " filled " with either the borate, carbonate or silicate of soda. These fillers have themselves distinct cleansing properties, so that their addition is not strictly to be classed as adulteration.

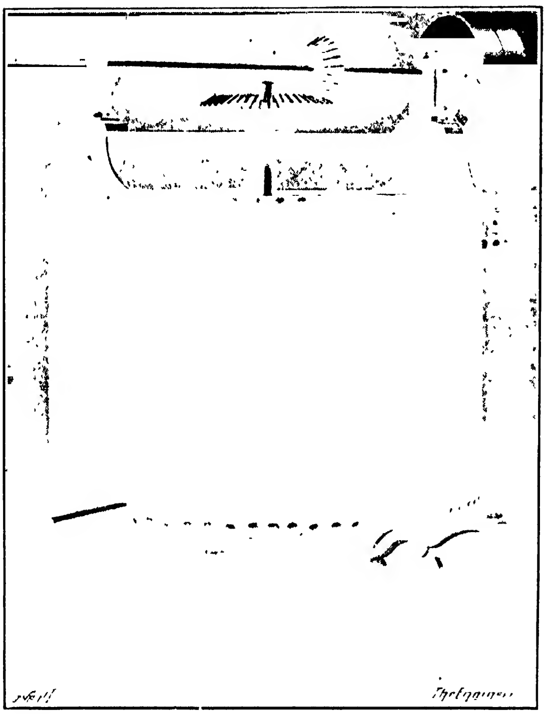


Fig. 77.—Crutching Machine—Timmins.

A crutching machine made by E. Timmins & Sons, Ltd., Runcorn, is shown in Fig. 77. It consists of a double-walled steam-jacketed cylindrical vessel containing a vertical power-driven shaft, from which four or more beater arms extend horizontally. Six or more fixed arms springing from the inner surface of the vessel co-operate with the rotating arms. Very frequently the crutchers are arranged in pairs, as shown in Fig. 78, where a twin set, made by R. Daglish & Co., Ltd., of St. Helens, is represented. The practice here indicated of driving the machines by an attached single-cylinder steam engine is quite usual, for it permits the exhaust steam from the driving engine readily to be utilised in the jackets of the crutchers. In Fig. 79 we illustrate in cross-section a steam-driven crutcher made by George Scott & Son (London), Ltd.

Soap Frames.

The soap, while still hot, is run out of the crutching machines into moulds or " frames," where it is allowed to cool and set. A typical soap frame, made by Messrs. Timmins, of Runcorn, is shown in Fig. 80. These frames have removable sides, so that they may be knocked down when the soap has solidified. They are frequently made of cast iron, but mild steel is now being commonly employed. The capacity of each is anything from 3 to 10 cwt. of soap.

Slabbing and Cutting.

The slab of soap, as taken from the frame, has to be cut up into bars, and these bars have, commonly, to be again cut into tablets. The original slab is first subdivided into several slabs of lesser thickness, and each of these is cut up into bars by means of a machine, such as that shown in Fig. 81. The machine illustrated is made by Messrs. Timmins, of Runcorn, and has a flat table whereon the divided slab rests. By means of a hand-wheel, crank discs, links, levers, and a guided crosspiece, the slab is pushed forward beneath a fixed bridge, from which a number of equally spaced piano wires extend vertically to the surface of the table. Means are provided for

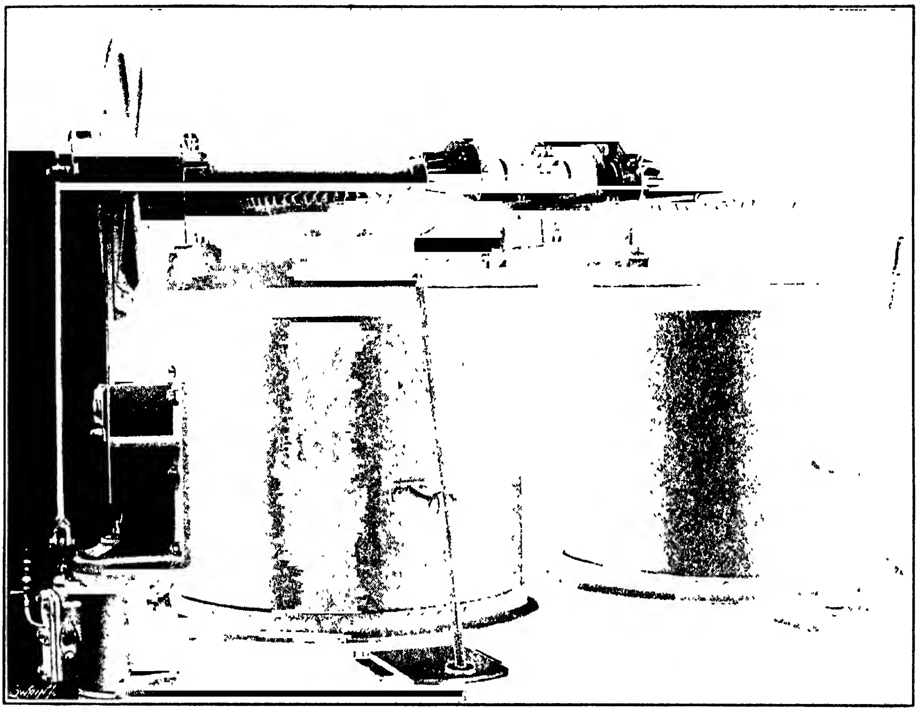


Fig. 78.—Twin Crutching Machines—Daglish.

adjusting the tension in the wires. The bars thus formed, if they are to be further divided into tablets, are taken, separately, to a cutting machine of the type illustrated in Fig. 82. The machine illustrated is made by Messrs. Daglish, of St. Helens. In the block of wood A a number of vertical saw cuts are formed, while along the top a vee-sectioned recess is provided for the reception of the bar of soap. The frame B is pivoted on a rod C at the back of the machine and carries a number of equally spaced piano wires, which register with the saw cuts in the block A. With the bar of soap in place the frame is simply pressed down by hand.

Drying.

The soap as thus cut into tablets contains round about 33 per cent. of water, and for this reason is comparatively soft and sticky. It is customary, therefore, to

subject it to a drying treatment, in order to form a crust of hard soap round the soft interior. By so doing further evaporation from the body of the soap is retarded and the weight is preserved. In addition, the drying of the crust is es ential, if, as is frequently the case, the tablets after cutting, have to be pressed. It is impossible to carry out this pressing if the crust is not hard, for the sticky soap is bound to adhere to the press dies. Practice as regards drying has recently undergone a change. Formerly, the soap was dried simply by placing it in a room heated by steam pipes or coils. The improved modern method makes use of a warm air blast. Apparatus for this purpose, made by Messrs. Fraser, of Dagenham, Essex, is illustrated in Fig. 83. It consists simply of a steam heater through which air is driven by an attached fan into a wrought-iron casing provided with hinged doors and containing several tiers of galvanised iron wire trays for holding the soap.

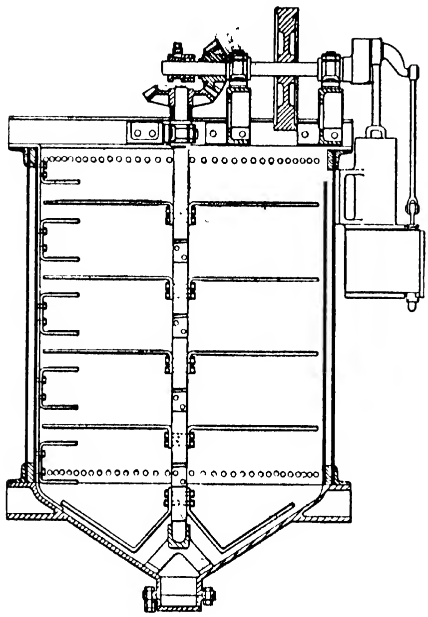


FIG. 79.—Steam Driven Crutcher—Scott.

STAMPING.

The rough tablets are, after being dried, very commonly stamped to improve their appearance. A hand-machine for this purpose, made by Messrs. Daglish, of St. Helens, is illustrated in Fig. 84. This machine is capable of dealing with either 1-lb. or ½-lb. tablets. It consists of two balanced fly-wheels united by a crosspiece with handle, and operating, through an arm, a plunger, which works within a sleeve pivoted at its lower end to the frame of the machine. The bottom of the mould box is loose, and is designed to rise on the up-stroke of the plunger, so as to eject the soap from the mould. The tablet is frequently stamped twice, once on each face.

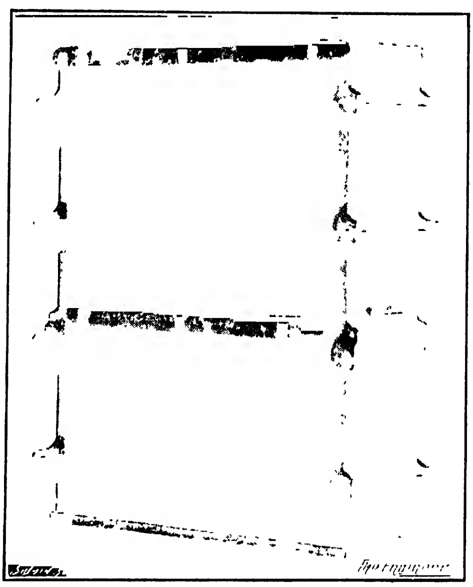


FIG. 80.—Soap Frame—Timmins.

CHIPPING AND MILLING.

Soaps prepared as described above are suitable for many purposes, notably for laundry and similar work. They are liable, however, with time to lose weight by shrinkage and otherwise to deteriorate. For the production of the best quality of toilet soaps, the process known as milling is resorted to. The first step in this process

is to reduce to chips the soap as taken from the frames. The slabs are first cut into bars and partially dried. Thereafter, they are taken to a chipping machine, such as

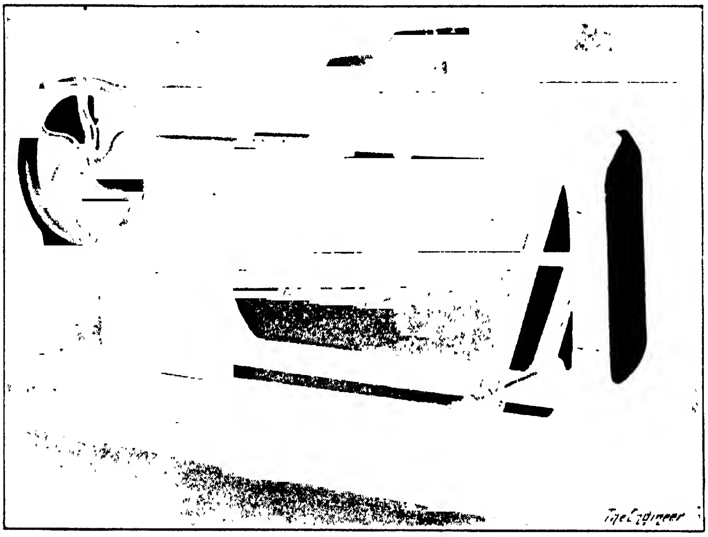


FIG. 81.—Slab Cutting Machine—Timmins.

that shown in Fig. 85, which illustrates a double-sided machine made by Joseph Baker & Sons, Ltd., of Willesden Junction, London. The bars of soap are placed in the

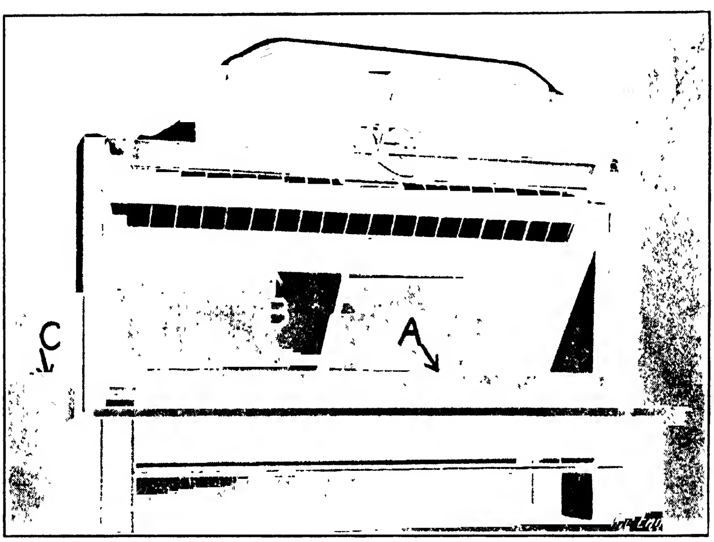


FIG. 82.—Bar Cutting Machine—Daglish.

shoots shown, so that their ends may come in contact with the blades of the rapidly revolving cutters disposed within the casings. The chips fall from the foot of the casings on to trays supported on the angle-iron runners shown. The thickness of the chips can be regulated to suit requirements.

The chips are next dried until they contain round about 10 per cent. of water. For this operation the drying plant illustrated in Fig. 83 is suitable. Colouring and

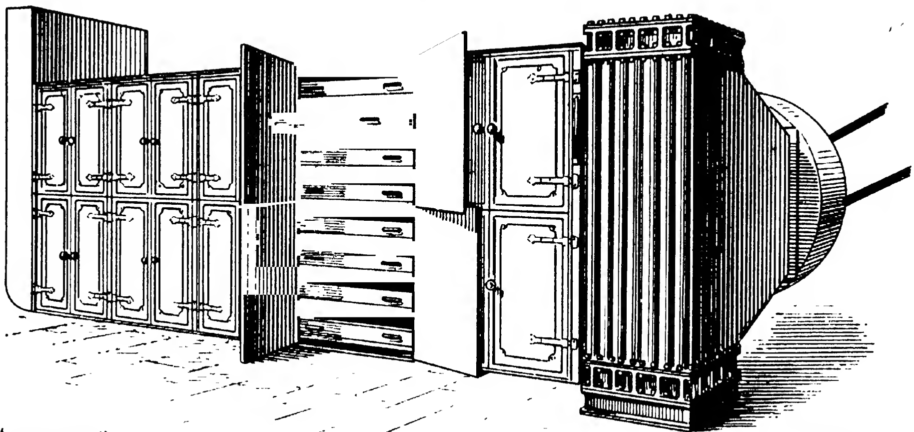


FIG. 83.—Soap Drying Plant—Fraser.

scenting materials are then added to the dried chips, and the whole is ground up in a toilet soap mill. A machine of this description made by Messrs. Baker, of Willesden Junction, is illustrated in Fig. 86. This mill consists of five granite, or syenite, rollers very carefully ground to truth. The rolls are 31 in. long, the four lower rolls being 13 in. in diameter, and the top roll 19 in. The lowest roll and the third roll run at a relatively slow speed. The second and fourth rolls run at about twice this speed, while the top roll runs at about four times the speed of the lowest roll. A double hopper is arranged in front of the rolls. The soap chips are fed into the lower division of this hopper and pass thence to be ground between the differentially moving rolls. As the material comes round the fifth roll, it is scraped off into the upper division of the hopper. When the whole batch has accumulated in this division a shutter at the foot is withdrawn, and the charge allowed to return to the lower division for a second pass through the mill. From four to eight passages are frequently given to the material, the number depending upon the quality desired in the resulting product. At the end of the last pass the soap is scraped off in the form of thin ribbons from the back of the top roller.

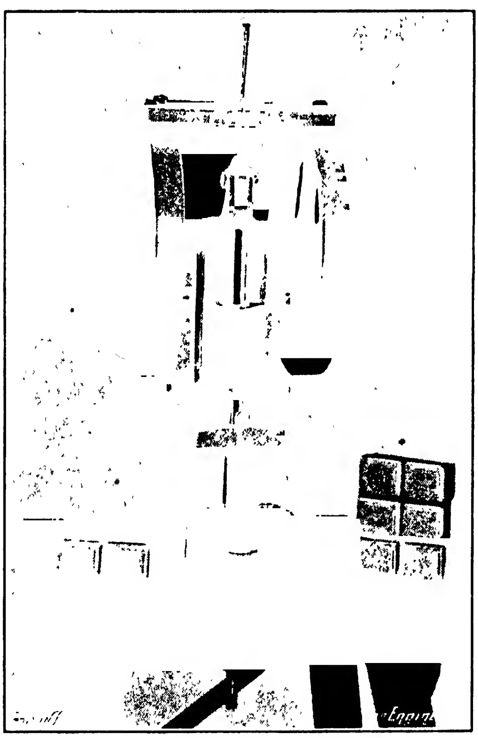


FIG. 84.—Stamping Machine—Daglish.

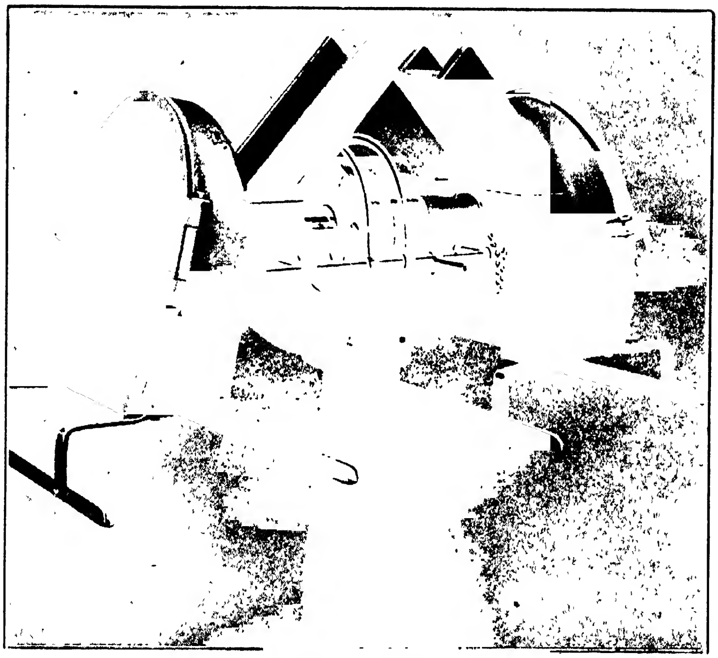


FIG. 85.—Chipping Machine—Baker.

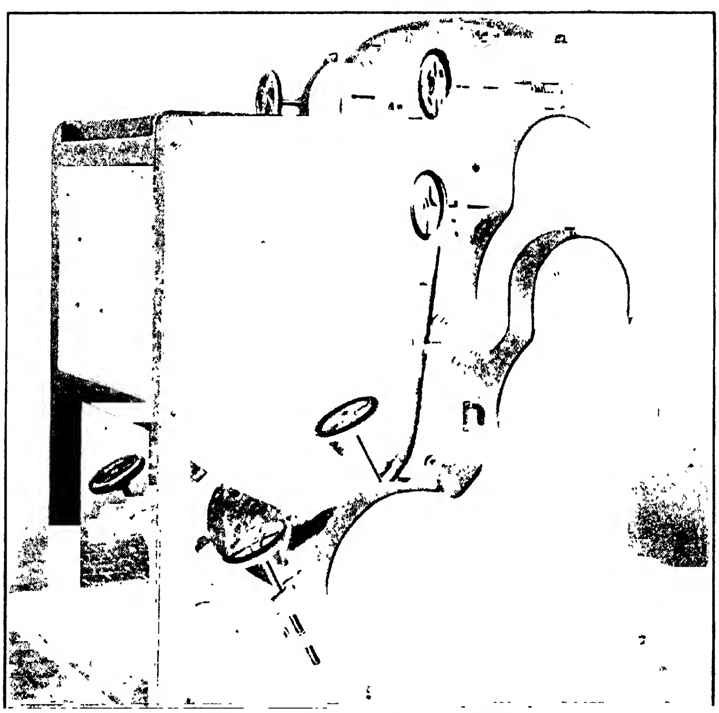


FIG. 86.—Milling Machine—Baker.

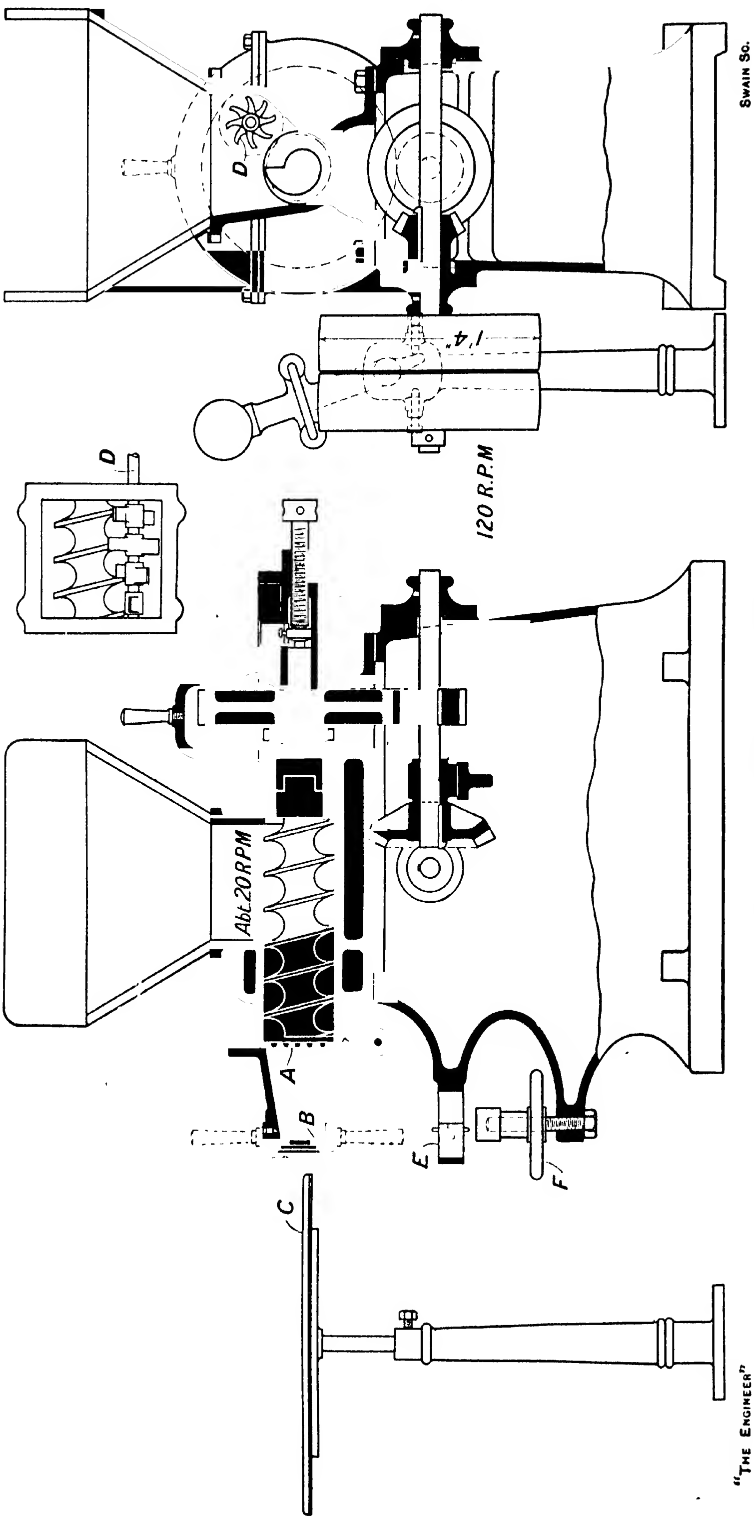


Fig. 87.—Soap Squeezing Machine or Plodder—Fraser.

The mass of ribbons is next transferred to a squeezing machine or "plodder," of which an example made by Messrs. Fraser, of Dagenham, Essex, is illustrated in Fig. 87. This machine squeezes the soap through a perforated die plate A, so that it comes out in the form of small round threads. Thereafter, the die plate is removed and the material is once more passed through the machine. As it passes through the die plate B at the end of the cone-like mouth-piece, the soap is squeezed into a solid bar, which is received on the table C and thence passed to a cutting and stamping machine. The squeezing of the soap through the die plates is effected by a short worm rotating at about 20 revolutions per minute at the foot of the hopper, and arranged coaxially with the conical mouthpiece. This worm is fed with soap from the hopper by the action of a finger shaft D within the hopper, and driven by gearing from the worm shaft. A heating jacket is provided round the worm, to facilitate its work on the soap. When the machine is stopped at the end of a run, the cone is still filled with soap. To remove this the cone is hinged so that it may be swung downwards and clamped within the bracket E. The die plate B having previously been removed together with the cover or cap, which holds it in place, the hand-wheel F is operated so that the piston-like head formed on it may rise within the cone and eject the soap upwards. The output of this machine is from 3 to 5 cwt. per hour. A modification is sometimes to be found in use. In this the squeezing machine is combined with the milling machine. It is very doubtful if such a combination is as satisfactory as keeping the two machines apart.

CHAPTER XVI

GLYCERINE RECOVERY AND REFINING AND THE SPLITTING OF OILS.

GLYCERINE and a fatty acid are, as we have remarked, the two essential parts of every animal or vegetable oil or fat. It must not, however, be thought that such an oil or fat consists simply of a mixture of these two substances. In reality neither glycerine nor fatty acid should exist separately as such in a neutral oil or fat. If they do, particularly if free fatty acid is present, we have a sign that the oil or fat has suffered some decomposition.

The matter may be put with advantage in a popular way without introducing cumbersome chemical formulæ. A molecule of oil consists of a molecule of glycerine—less an atom of hydrogen and an atom of oxygen—and a molecule of fatty acid—less an atom of hydrogen. It will be noticed that the missing atoms together constitute a molecule of water. If this molecule of water can be added to the oil under suitable conditions then the molecules of glycerine and fatty acid will be made complete and will separate from one another. If, instead of water, HOH, we add a molecule of caustic soda, NaOH, the glycerine is again made complete, but the fatty acid molecule receives a sodium instead of a hydrogen atom, and separates not as a fatty acid, but as a soap. Lime, $Ca(OH)_2$, acts similarly and yields glycerine on the one hand, and a lime soap, insoluble in water, on the other. Caustic potash, KOH, also acts in the same manner, giving glycerine and soft soap ; and so on for other hydroxides.

The splitting up of vegetable and animal oils into glycerine and fatty acid forms an important branch of industry, and is carried out in a variety of ways. Thus it can be directly effected by subjecting the oil to the prolonged action of superheated steam—a fact which explains why animal and vegetable oils are not so popular as mineral oils for lubricating parts of machinery and engines subjected to high temperatures. The splitting up can also be achieved by treating the oil with lime, drawing off the glycerine thus set free, and treating the lime soap further with sulphuric acid to convert the soap into fatty acid with the liberation of calcium sulphate. There are several other important processes of carrying out the work. Their object is, of course, to obtain the valuable glycerine by a direct method, and to recover the fatty acid as a by-product, which may be sold to the soap maker or candle maker.

The soap maker, as we have stated, very frequently prefers to work with the whole oil or fat and not with the fatty acid by-product of the de-glycerinising works. He prefers to do so because the glycerine thus comes under his own control, and forms a valuable adjunct to his business. Apart from this it is believed that the recovery of the glycerine is more complete if performed after the soap has been made than it is if the oil or fat is split beforehand. Again, the recovery of the glycerine if performed at the soap works enables the soap maker also readily to recover the salt which he uses to separate the soap in the kettle. Finally, it is stated that the production of soap from fatty acid stock requires much more skill than is necessary if an unsplit oil or fat is used. In this chapter we propose to deal, first, with the recovery of the glycerine set free as a result of the soap-making process ; secondly, with the splitting of oils and fats as carried out in de-glycerinising works and elsewhere, and finally with the refining of crude glycerine.

Glycerine—or glycerol, to give the perfectly pure body its proper scientific name—is present in all vegetable and animal oils and fats to the extent on the average of about 10 per cent. by weight. It is, of course, known to the public as a colourless, odourless, sweet-tasting, syrupy liquid, but its fluidity appears to be due to its impurity. Pure glycerine is a solid at all temperatures up to about 17° C., at which point it melts. In its common form it is a liquid weighing about 1¼ times the weight of an equal volume of water. It is combustible, and burns to water and carbon dioxide. Its boiling-point, like that of water and other liquids, depends, of course, upon the pressure to which it is subjected. At normal atmospheric pressure it boils at 290° C., and in so doing suffers some decomposition. Its distillation cannot therefore be satisfactorily performed except under a reduced pressure. At an absolute pressure of 1 lb. per square inch it boils at 210° C., and at one-tenth of a pound per square inch it boils at 163° C. It can be mixed with water in any degree, but is insoluble in benzene, carbon disulphide, and oils. The two first-named substances, as we have seen, readily dissolve oil. They will not, however, dissolve glycerine when separated from the fatty acid combined with which it forms an oil. On the other hand, glycerine itself is a very ready solvent for a large number of substances, rivalling, and at times surpassing, water in this respect. Among such substances are many metallic salts and halogen compounds, certain metallic oxides, caustic alkalies, and various metallic soaps, that is to say, soaps in which the sodium or potassium is replaced by other metals such as iron, magnesium and calcium.

Recovery of Crude Glycerine from Soap Works Spent Lyes.

All the facts we have just mentioned have an important bearing on the problem of recovering the glycerine from the "spent lyes" of a soap works. The spent lyes run off from a kettle in which hard, *i.e.*, soda, soap, has been made, consist of water in which various bodies are dissolved, and with which small proportions of various insoluble substances are mixed. They contain first of all nearly the whole of the glycerine combined in the original oil or fat from which the soap has been made. This constituent may amount to, say, about 6 or 7 per cent. of the whole, and is, of course, dissolved in the water. Next in importance comes the salt—sodium chloride—which in the soap-making process is thrown into the kettle to cause the soap to rise and separate itself from the rest of the contents. This salt is dissolved in the solution of glycerine and water, and is present in sufficiently large quantity to make its recovery from the lye an important element in the economy of the soap works. The lye also contains in solution a small amount of the caustic soda used to saponify the oil or fat, for it is impossible to work with just that amount of soda which is necessary to effect the saponification of the given quantity of oil or fat. The excess soda is dissolved in the glycerine-salt solution. The glycerine, salt, and soda are the three chief constituents of the aqueous lye, and would be the only constituents if everything were theoretically perfect. In practice, however, the oil or fat, the salt and the soda, are never pure or anything like it. The oil or fat is sure to contain mucilage and albuminous matter, while the soda and salt between them contribute various chemical impurities, such as metallic salts and sulphates, sulphides, and other bodies. These pass into the lye unaltered, or in combination. In addition, the lye nearly always contains a small amount of soap, for sodium soap is not completely insoluble in salt water.

The spent lye is thus a very complex substance. For many years it was regarded as practically useless, it being held that the cost and trouble of recovering the glycerine from it were too great to make the undertaking pay. Glycerine in those days was in very limited demand. With the invention of dynamite and nitro-glycerine, substances

which to-day afford by far the greatest outlet for glycerine, the circumstances were altered, and great attention came to be paid to the recovery of glycerine by soap makers.

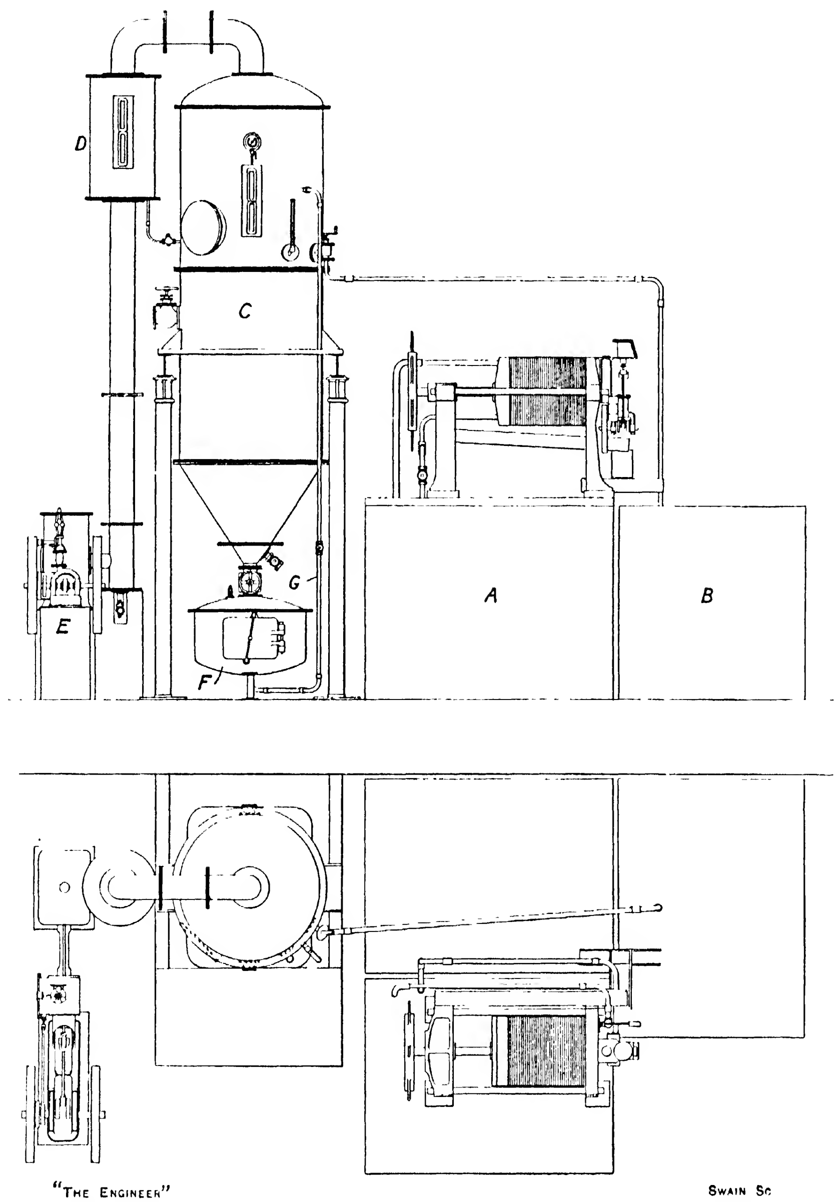


Fig. 88.—Single Effect Vacuum Evaporator for Concentrating Crude Glycerine—Scott.

Its enhanced value then made it profitable to devote considerable pains to its recovery, and to this was added as an incentive the practicability of recovering the salt simultaneously from the lyes. To-day, soap makers, as a rule, have modified their soap-making practice to the end that the glycerine may be recovered more readily and in

a purer form than used to be the case. In particular they have largely abandoned the use of certain crude saponifying chemicals in favour of others which are less likely to contribute undesirable impurities to the lye.

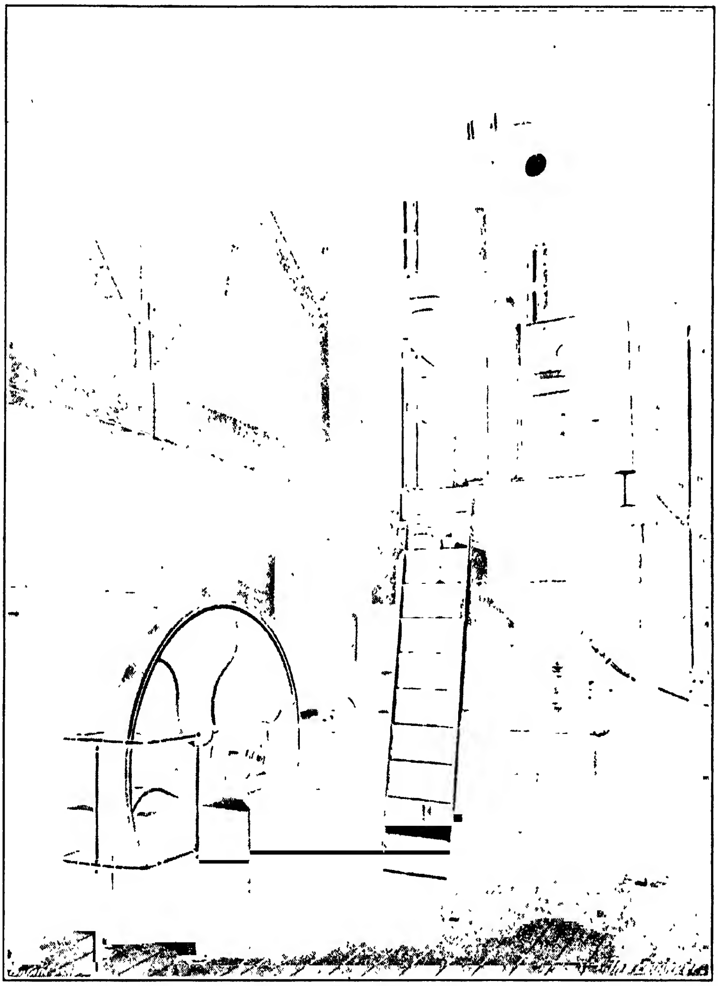


FIG. 89.—Single-effect Vacuum Evaporator for Concentrating Crude Glycerine Scott.

PURIFYING THE LYE.

The first step in the treatment of the lye is to acidify it. This is commonly done by running it into a tank and adding hydrochloric acid to it. The result of this is that the free caustic soda is converted into common salt and water, while any soap dissolved in the lye is decomposed into free fatty acid and common salt. Simultaneously, iron sulphate, aluminium sulphate or common alum is added to the lye. This combines with the free fatty acid to form a metallic soap, which, being insoluble, is precipitated. At the same time, these chemicals coagulate and precipitate the

albuminous and other colloidal matter in the lye, just as they do in the case of their application to sewage purification.

The treated lye is then passed through a filter press and sent into a second tank. It consists now, primarily, of water, glycerine and common salt, with the excess of hydrochloric acid and ferric or other sulphate added during the preceding treatment as impurities. Caustic soda is, therefore, carefully added to it until it becomes neutral by the conversion of the hydrochloric acid into salt. The soda also acts on the ferric or other sulphate, the result of the reaction being the precipitation of insoluble iron hydroxide and the formation of sodium sulphate which passes into solution in the glycerine, salt and water lye. The liquid is now once again filtered and is passed into a third tank, whence it is withdrawn as required for further treatment.

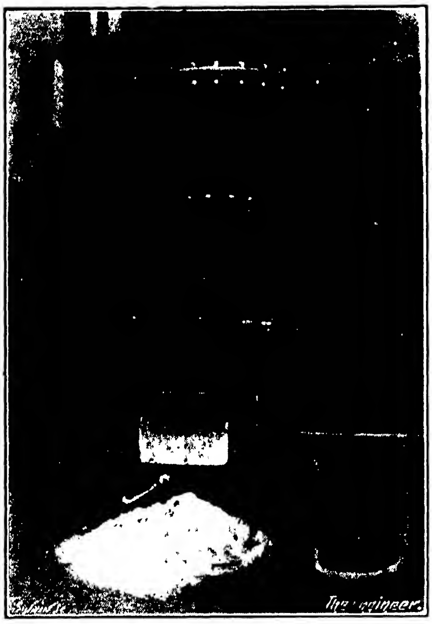


FIG. 90.—Removing Salt from a Vacuum Evaporator.

CONCENTRATION.

This further treatment consists of concentrating the liquid by the evaporation of its water portion. As the concentration proceeds the salt, or the bulk of it, is thrown out of solution and can ultimately be collected and used again in the soap kettle. It is clear that all the salt cannot be removed from the lye simply by evaporation of the water. Even if the evaporation were carried to completion there would still remain a fair amount of salt dissolved in the glycerine left behind. As a fact, the liquid resulting from the evaporation is what is known as crude glycerine, and at the best consists of, say, 80 per cent. of pure glycerine and about 10 per cent. of salt, the remainder being water and certain chemical impurities.

The plant employed for evaporating the treated lye at one time consisted of fire-heated pans. These were succeeded by open-air steam-heated vessels. The fact, however, that high temperatures or prolonged heating reacted unfavourably on the glycerine, was soon recognised, and as a result, vacuum evaporators were introduced. These not only effect the evaporation quickly and at a reduced temperature, but economise fuel by permitting exhaust steam to be used for their heating.

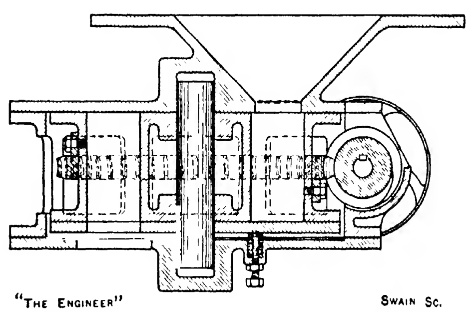


FIG. 91.—Automatic Salt Discharging Device.

A typical example of a modern single effect vacuum evaporator for the recovery of crude glycerine, as made by George Scott & Son (London), Ltd., Kingsway House, Kingsway, W.C. 2, is illustrated in Figs. 88 and 89. The liquid having been filtered

from the second treatment tank A into the third tank B is drawn up by the vacuum into the evaporator C—Fig. 88. This vessel is provided with a tube plate near the top and near the bottom. Between these plates extend a number of vertical tubes up which the liquid is caused to rise. The space outside the tubes and between the tube plates is filled with heating steam. The tubes are of two diameters, and are so arranged as to promote a vigorous and uniform circulation without recourse to mechanical means. It is essential to have a good circulation in these evaporators, for otherwise the salt, as the evaporation proceeds, will deposit on the interior of the tubes and restrict or choke them, instead of falling, as it is intended to do, into the conical end of the evaporator below the lower tube plate. A good circulation may further be relied upon materially to reduce the chance of the liquid "frothing" and boiling over. To eliminate all danger from this cause, however, Messrs. Scott fit a "catch-all" D or trap with internal baffles to intercept the overflow and return it to the evaporator.

The vaporising space above the upper tube plate is connected by a pipe to a vacuum pump E of special design. The pump plunger works beneath a body of water in a tank; by the displacement of this water the steam is drawn over from the evaporator and delivered through a jet condenser. The lower conical end of the evaporator is in communication with a vessel F, into which the salt falls as the evaporation proceeds. When the salt vessel is full it is isolated from the evaporator by means of a sluice valve. The further precipitation of salt is allowed to accumulate in the conical end of the evaporator until the vessel F has been cleared. Before the door of the salt vessel is opened a valve on the pipe G is operated to place the vessel for a short time in communication with the vacuum inside the evaporator. The salt resting on a metallic filter inside the vessel is thus drained of most of the liquid adhering to it, which liquor is returned to the evaporator. Steam is now turned on into the salt vessel, so as to wash and dry the salt as far as possible. The washings are returned by the pipe G to the evaporator. The door of the vessel can then be opened—see Fig. 90—the salt removed, and the vessel once again put into communication with the evaporator. The salt thus removed is comparatively dry, and can be re-used immediately in the soap kettles.

For large plants an automatic arrangement is frequently fitted by Messrs. Scott, in place of the vessel F, whereby the salt is discharged continuously. This device is illustrated in Fig. 91. Its construction is simple and obvious. In this case the salt is discharged moist and saturated with liquor, and is immediately dried and washed in a centrifugal machine. In Fig. 92 we give a view of a large glycerine recovery plant capable of dealing with 500 tons of spent lye per day. This plant is fitted with the automatic salt-extracting arrangement referred to, and with mechanical means for conveying the salt to and from the centrifugals.

The evaporation of the liquor and the extraction of the precipitated salt are proceeded with until, as we have said, the liquor shows a concentration representing an 80 per cent. content of glycerine. This condition is judged by noting the temperature of the liquor in the evaporator, for as the water is eliminated the boiling-point of the liquor left rises. At any given pressure above or below atmospheric, there is a definite boiling point for each and every strength of liquor. In the neighbourhood of 80 per cent. concentration the boiling-point rises by about 1° C. for each 1 per cent. increase in the concentration. It may be remarked that even at atmospheric pressure the boiling-point of an 80 per cent. solution of glycerine in water is no more than about 120° C., and under a vacuum it is, of course, still less. Hence exhaust steam, if available, will in most cases be quite sufficient for heating the evaporators.

When the concentration has reached the desired degree the vacuum pump and jet condenser are closed down, and the crude glycerine is run off into store tanks. A fresh charge of liquor, which in the meantime has been treated chemically in the manner described above, is immediately introduced into the evaporator

The apparatus described so far is of the "single effect" type, and is suitable for use where the supply of exhaust steam is abundant. Where it is not, and where fuel

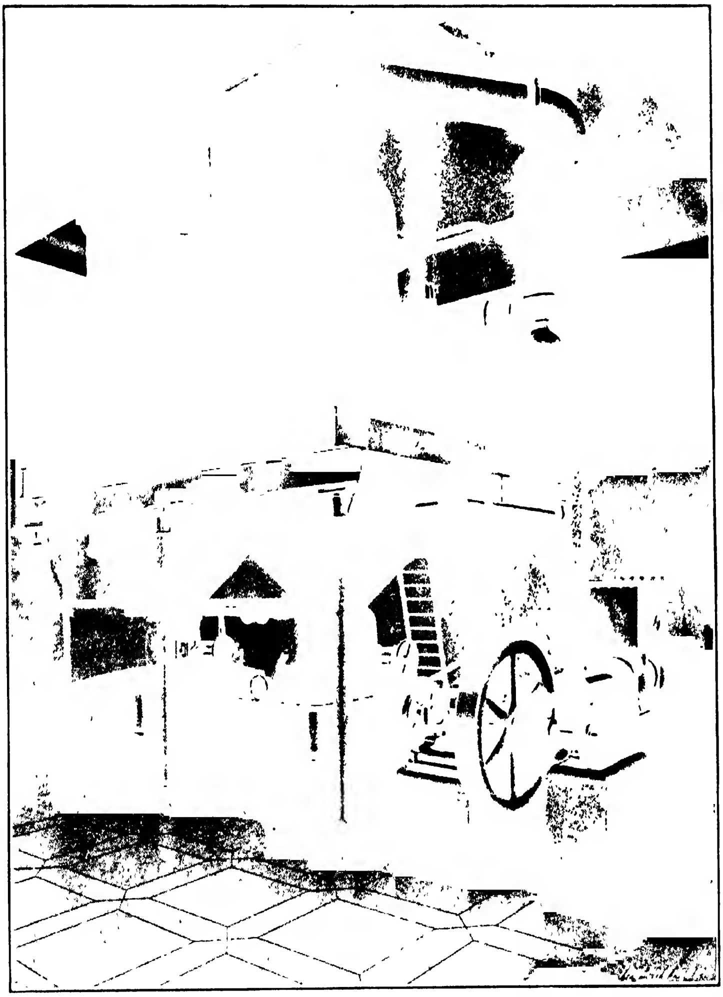


FIG. 93.—Double-effect Vacuum Evaporator for Concentrating Crude Glycerine.

is expensive, it is usual to employ a double-effect evaporating plant of the type illustrated in Fig. 93. In such a case live steam is supplied to the first evaporator only. This evaporator is worked at a pressure not much less than atmospheric, so that the vapour developed in it may be sufficiently hot to be utilised as the heating fluid for the second evaporator. This second evaporator works at a high vacuum. The liquor receives a preliminary concentration in the first evaporator, and is then passed on for final treatment in the second. Usually nearly all, if not the whole of the salt is

deposited in the salt vessel of the second evaporator. The first, however, is also fitted with a salt vessel, so that either evaporator may be run on the single-effect principle should repairs to one unit or any other cause render this desirable. The plant shown in Fig. 92—already referred to—consists of four double effect evaporators.

The presence of the salt in soap makers' waste lyes is undoubtedly a disadvantage when it comes to the problem of recovering the glycerine. The crude glycerine, as we have said, is bound to retain a considerable percentage of the salt. Even the subsequent refining of the glycerine by distillation may not entirely eliminate it. With the increased demand for pure glycerine which has arisen with the development of high explosives, more and more attention has come to be paid to alternative methods of obtaining the crude product, methods which do not involve the glycerine being brought into contact with salt at any point or with more than a small amount of any other chemicals.

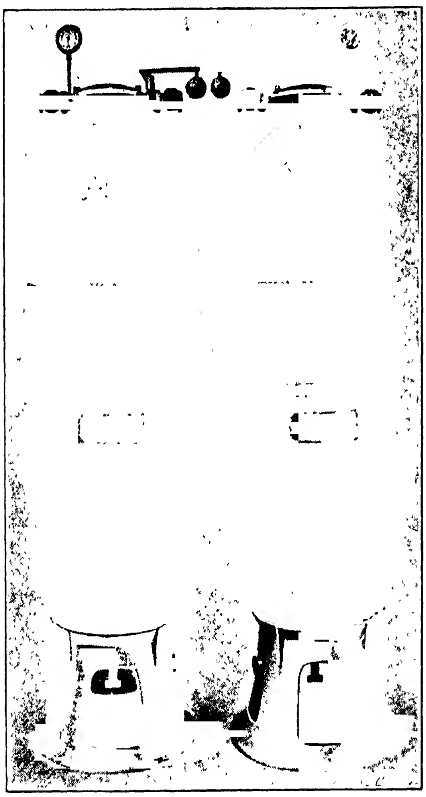


FIG. 94.—Oil and Fat Splitting Autoclaves—Scott.

THE SPLITTING OF OILS AND FATS.

The "splitting" of oils and fats can be performed in several ways. Roughly stated, the object aimed at is to make each molecule of oil take up a molecule of water, so as to form a molecule of glycerine and a molecule of free fatty acid, or, to speak scientifically, to "hydrolise" the oil. We have already mentioned in a previous chapter, that the hydrolysis of an oil once started is liable, if water be present, to continue automatically until a very considerable proportion of the oil is converted into a mixture of glycerine and free fatty acid. In the case of palm oil, for example, the prevention of hydrolysis is very difficult if not impossible. We are now dealing with an aspect of affairs in which the encouragement of hydrolysis may be said to be the direct object in view.

AUTOCLAVE PROCESS.

The two principal methods of splitting oils are the autoclave method and the Twitchell process. A pair of autoclaves for oil or fat splitting by Messrs. George Scott & Son is illustrated in Fig. 94. These are simply cylindrical heating vessels and, as shown, are usually not provided with agitating gear. The fat or oil is introduced into the autoclave together with 1 or 2 per cent. of some base, such as lime, magnesia, barium oxide or—very commonly to-day—zinc oxide. Steam at a pressure of, say, 150 lb. is then admitted to the autoclave, the pressure being maintained for from four to six hours. The small amount of chemical base used is sufficient to start the decomposition of the oil or fat into glycerine and a lime, magnesia, etc., soap. This, once

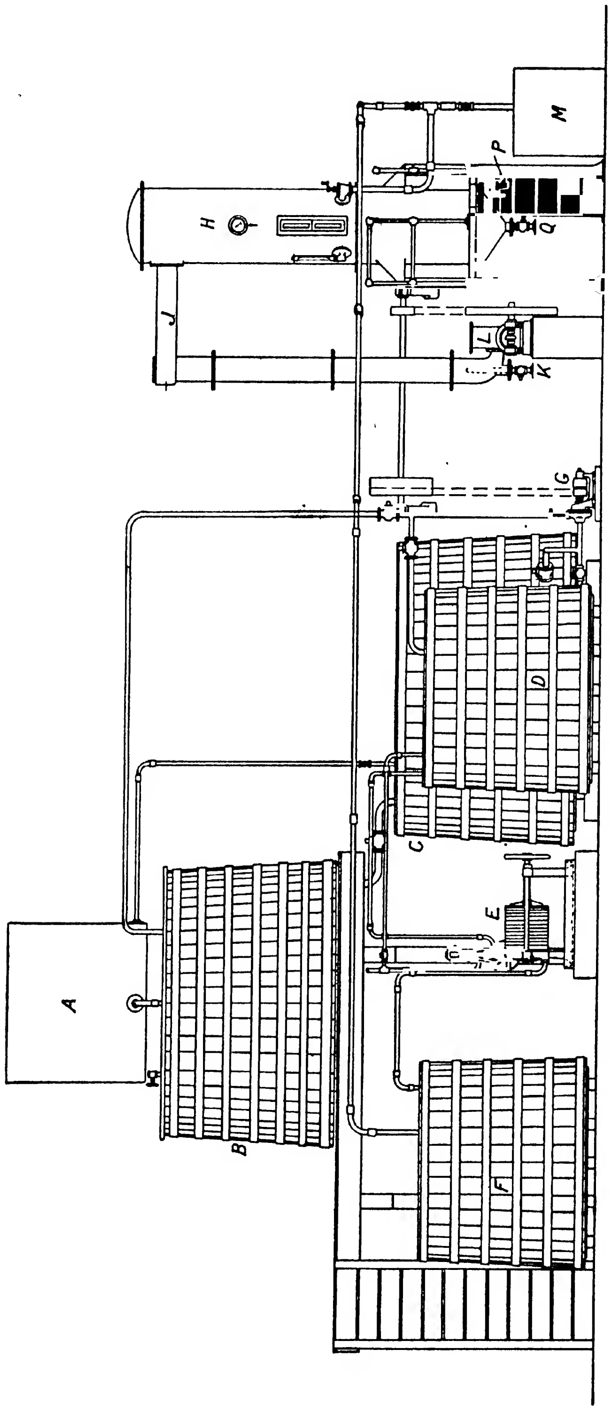
started, induces hydrolysis, and the rest of the oil or fat taking up water from the steam becomes converted to glycerine and fatty acid.

Thereafter the contents of the autoclave are treated with a small amount of acid to decompose the soap formed by the base into fatty acid and a lime, magnesium or other salt. The fatty acid and the glycerine are then separated by taking advantage of their difference of specific gravities. The glycerine contains much water—it is known at this stage as "sweet waters"—and is filtered and concentrated. The concentration is effected in an evaporator similar to that described above in connection with the treatment of soap makers' lyes. No salt extracting details are, however, provided, for no salt is present in the liquor. About 95 per cent. of the oil or fat originally introduced into the autoclave is on the average converted by this method, although at times as much as 98 per cent. can be completely split. The remainder passes away unchanged with the fatty acid.

The Twitchell Process.

An important alternative method to the above is Twitchell's process. If oleic acid—a fatty acid occurring in many oils and fats—and benzene, naphthalene, or certain other bodies are mixed and treated with sulphuric acid a certain compound results, known as Twitchell's reagent. This compound may popularly be said to have the power of fermenting oils and fats when boiled with them at atmospheric pressure, for it readily hydrolises them into glycerine and fatty acid. The fact that the action is satisfactorily effected at atmospheric pressure gives the Twitchell process certain advantages over the autoclave method. In particular, it permits the process to be conducted in wooden vessels.

In Fig. 95 we give the general arrangement of a splitting plant on the Twitchell system, erected by Messrs. George Scott & Son. To secure success with this process the oil or fat must first be freed from iron, lime, and other impurities. Accordingly, it is initially boiled with sulphuric acid in the lead-lined wooden vat B. The coagulated impurities sink to the bottom, and the clean oil is drawn off from a point near its surface level and is passed into the "saponifying vessel" C. Here it is mixed with from one-third to one-half of its weight of distilled water drawn from the tank A, and with from ½ to 2 per cent. of the Twitchell reagent. The charge is then agitated and boiled for a period extending up to twenty-four hours by means of steam delivered direct into it from a perforated coil within the vat. A close-fitting wooden cover is provided for the vat which, while allowing steam to escape, prevents the free access of air to the charge. This is desirable, because the hot fatty acid set free from the oil is liable to darken in colour in the presence of air in excess. When the boiling is completed the charge is allowed to stand until the fatty acid portion rises to the top and the glycerine and water portion sinks to the bottom. The latter is drawn off into the tank D, where it is neutralised with lime water and allowed to settle. The fatty acid portion may be boiled up again with water to extract the last traces of free glycerine. Any sulphuric acid in it is neutralised with barium carbonate, the addition of which to the charge results in the precipitation of barium sulphate. The neutralised glycerine water is pumped through the filter press E into the tank F. The separated fatty acid is drawn off from the tank C by the pump G. From the tank F the glycerine water is passed into the evaporator H. This is of similar construction to the vacuum evaporators used for concentrating soap makers' crude glycerine, except that no salt-discharging details are fitted to it. The vapour drawn off from the evaporator down the pipe J by the vacuum pump L is condensed by the water injector K and is sent as distilled water into the store tank A. Storage tanks for the partially concentrated



Elevation.

Fig. 95.—Plant for Splitting Oils and Fats by the Twitchell Process—Scott.

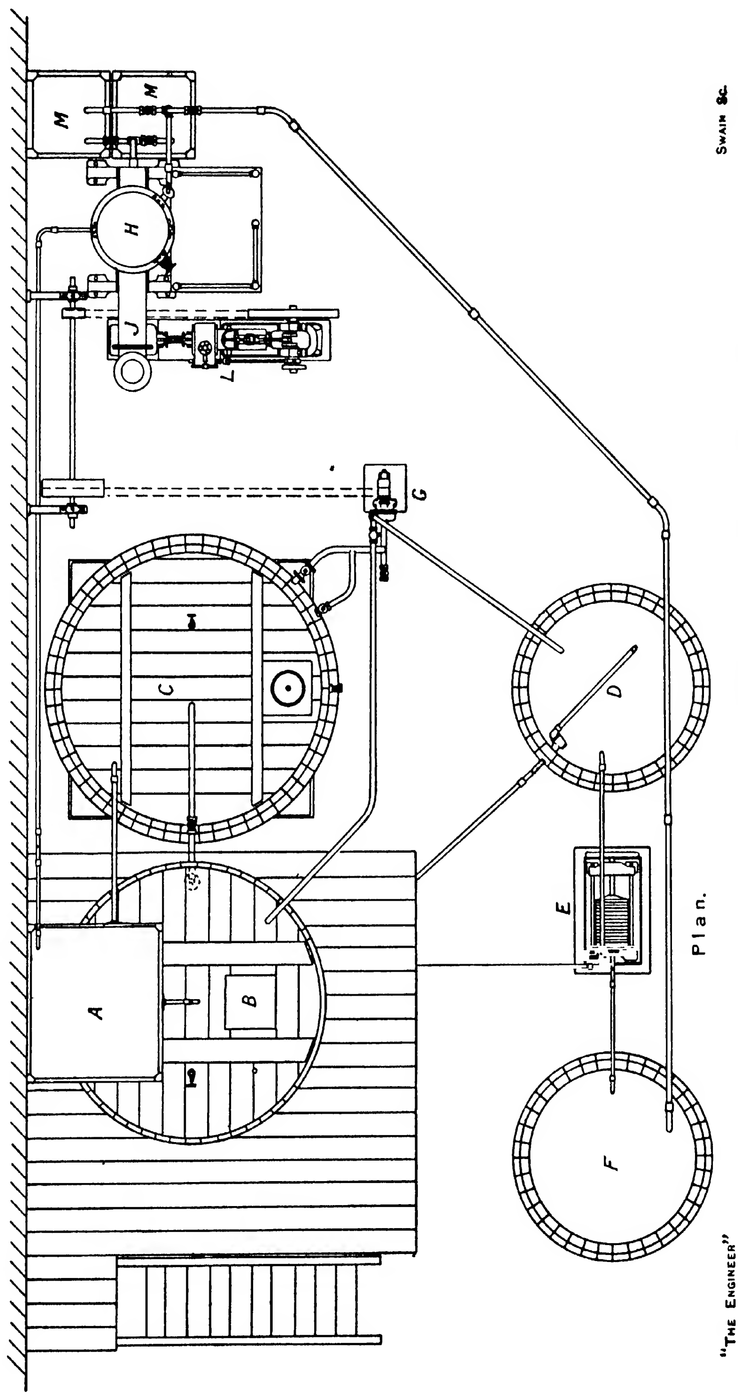


FIG. 95.—Plant for Splitting Oils and Fats by the Twitchell Process—Scott

glycerine drawn from the evaporator are indicated at M, M. In these the glycerine is allowed to settle and deposit any sediment it may hold. The partially concentrated glycerine may be returned for further concentration to the evaporator, and is then finally discharged at Q. P is a sampling cock.

Glycerine Refining.

The crude glycerine recovered from soap makers' lyes after concentration may contain up to about 80 per cent. of pure glycerine. The remainder consists of, say, 10 per cent. of water and 10 per cent. of salt and other impurities. The crude glycerine derived from the autoclave or Twitchell process of splitting oils or fats contains on the average about 85 per cent. of glycerine. The remainder is largely water, but there is also present a considerable amount of organic and inorganic impurities. To a certain small extent the crude glycerine obtained by either of these methods is used directly ; but for the two chief outlets for the substance, namely, in the manufacture of high explosives and in pharmacy, it is essential that the impurities and the water should be practically eliminated. This elimination is effected by distilling the crude glycerine under vacuum followed by concentration.

The refining or distillation of glycerine is practically an industry by itself. Usually, for instance, the soap maker does not carry his work beyond the stage of recovering the crude glycerine. This he disposes of to the glycerine refineries. Even some of the largest producers of crude glycerine regard it as their final market product, and do not attempt to refine it themselves.

As we have said above, glycerine distils under atmospheric pressure at 290° C., and in so doing suffers some decomposition. It cannot therefore be satisfactorily distilled at ordinary pressure by means of dry, external heat. In practice the method adopted is to heat it in a vacuum by, and in the presence of, superheated steam. The crude charge thus distils without decomposition of the glycerine, but the distillate, it must be noted, is not pure glycerine. It consists of glycerine vapour accompanied by water vapour, and the vapour of any of the impurities in the crude charge which are volatile. Among the latter we may include common salt, for if this body is not actually volatile at the pressure and temperatures employed it would appear that it is carried over in the distillate mechanically with the water vapour, and is found in the condensed distillate. The procedure adopted for glycerine refining is to condense the distillate in several different fractions. Those condensed at the highest temperatures will be purest and richest in glycerine. As the condensing temperature becomes less the percentage of glycerine in the condensate falls, until in the last condenser the condensate consists of little more than water contaminated with various chemical impurities.

The diagrammatic arrangement of a glycerine refining plant by Messrs. George Scott & Son is given in Fig. 96, while in Fig. 97 we give a view taken in a glycerine refinery fitted up by the same firm. Referring to the diagram, A is a steel still. Into this the crude glycerine, previously heated for preference, is introduced until the still is about half full. The remainder of the charge is added as the distillation proceeds. The still is fixed close to a furnace B, the prime object of which is to fire the superheater C, which supplies the still with steam. Incidentally the waste gases from the furnace are used to assist in maintaining the temperature of the still contents. The superheated steam is admitted both to closed and open coils inside the still. The bulk of the distillation, however, is effected by the steam issuing direct into the charge from the open coils. At D is indicated the inlet for the charge of crude glycerine, and at E is shown the discharge cock for the " still bottoms," that is, the residue left after the

distillation is over. The glycerine and steam vapours leave the still by the pipe F, and pass into the coooling battery G. In the case of the plant represented in the diagram the distillate can be condensed in nine different fractions. From six to nine fractions are usual. The cooling battery G gives seven simultaneous fractions. It consists of seven intermediate receivers H and seven final receivers J. The intermediate receivers are connected in pairs by means of six series of air-cooled bent pipes K. Radiation and atmospheric convection result in the establishment of a temperature

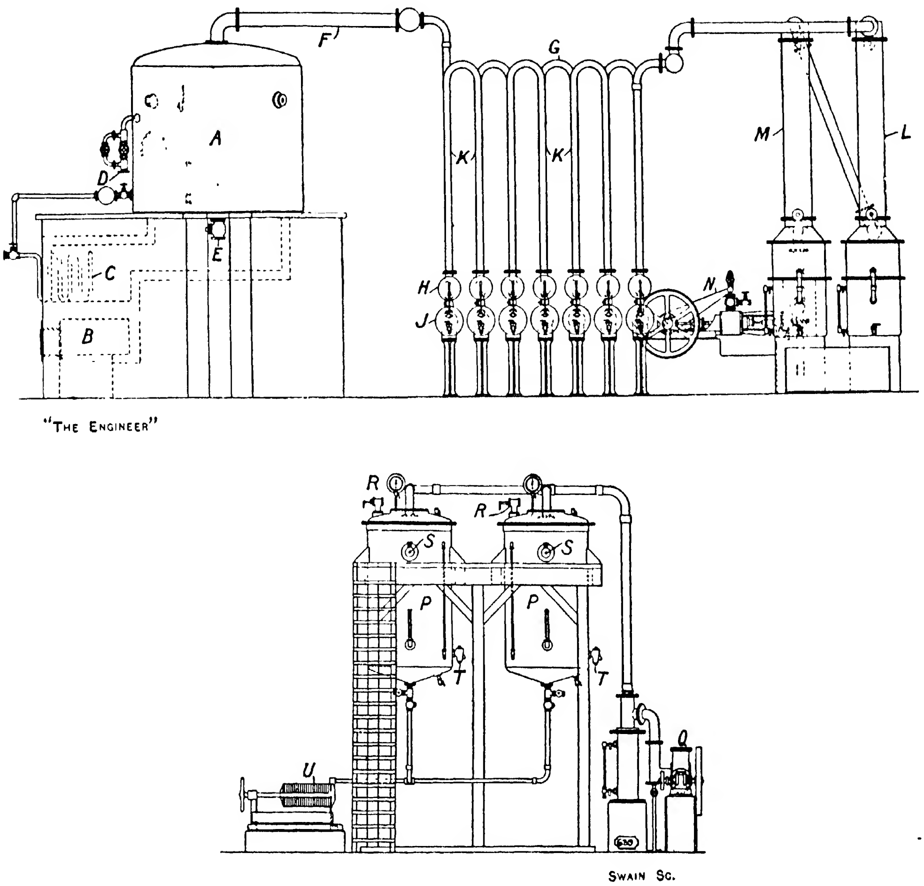


FIG. 96.—Glycerine Refining and Concentrating Plant—Scott.

gradient from pipe to pipe of the cooling battery. The most readily condensed portion of the distillate falls finally into the first of the receivers J, and is practically pure glycerine. In each succeeding receiver the condensate is increasingly rich in water and in volatile impurities.

The residue of the vaporous distillate leaving the last pipe of the cooling battery contains a small quantity of glycerine, and is passed into a water-cooled condenser L. In this all the glycerine should be condensed along with, of course, a considerable amount of the water vapour. What escapes from the condenser L is passed into a second water-cooled condenser M. In the ideal plant worked under ideal conditions

the condensate from M should be pure water. If this is attained then a guarantee exists that none of the glycerine is being lost, that all is being recovered.

In practice three storage tanks are commonly provided for the reception of the condensate. Into one of these are run those fractions from the cooling battery which are adjudged sufficiently free from chemical and other impurities to suit the purpose for which the glycerine is required. These mixed fractions contain a fair amount of condensed water vapour and have to be concentrated. Into the second storage tank are run those fractions of the distillate which are to be rejected because of their impurity. These are returned to the still for redistillation. Into the third tank is run the weak glycerine water derived from the condenser L. This fraction may be sufficiently free

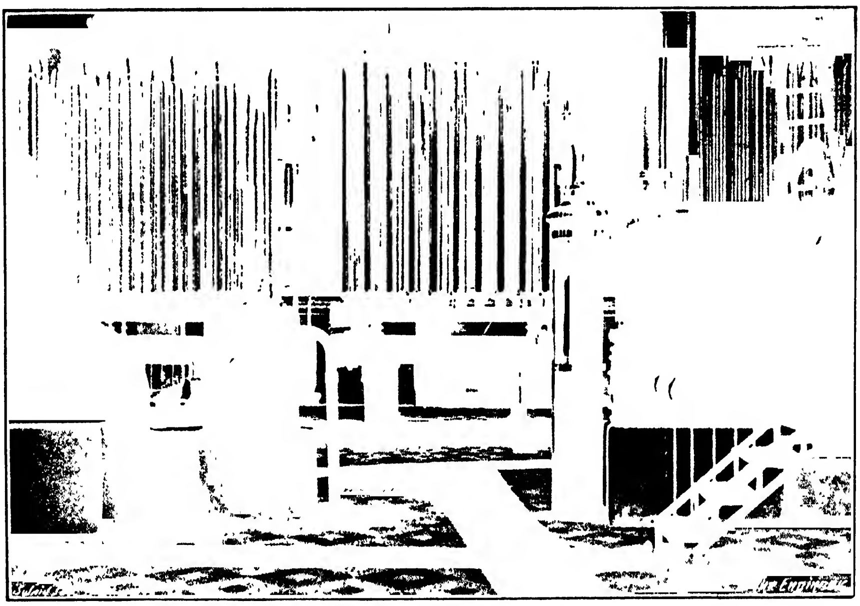


FIG. 97.—Interior of a Glycerine Refinery.

from impurities other than water to permit it to be added to the mixed fractions in the first tank so as to be concentrated along with them. It may, however, be sufficiently impure to require redistillation. If its impurity is not excessive it may be concentrated separately and sold for certain commercial purposes.

The still A, the cooling battery G, and the condensers L, M are maintained under the proper degree of vacuum by means of the pump N. The exhaust steam from this pump is used to assist in concentrating the selected fractions.

The concentrators P P are similar in principle to those already referred to in the earlier portion of this chapter. They are provided with a separate vacuum pump Q, and are fed with liquor through the inlets R. Steam is supplied to them at S. T T indicate sampling cocks. The finished glycerine is sent through a filter press U.

The product leaving the filter press is of a straw colour, and can be used without further treatment for the manufacture of explosives. The practice of bleaching the glycerine before making use of it in this way is now mostly discarded, as it adds little or nothing to the chemical purity of the material. For pharmaceutical purposes bleaching by means of high-grade animal charcoal is resorted to. It is usual to add

the charcoal to the glycerine while in the concentrator, and to pass and repass the liquid through the filter press until the desired brilliancy is obtained.

Glycerine of dynamite quality can usually be produced from crude glycerine obtained by splitting oils by one distillation. Frequently one distillation is also sufficient in the cause of crude glycerine from soap makers' waste lyes if the fractions retained for concentration are carefully selected. For chemically pure glycerine double distillation is commonly regarded as necessary.

Glycerine refining is a continuous process. A stoppage in the middle of the distillation may result in an increased amount of impure distillate, and may even reduce the total yield. In general, if soap lye glycerine is being treated the still should be cleared of it's " bottoms " at least once a week. These " bottoms ' consist of a black, tarry mass containing much common salt, and are practically valueless. In the treatment of crude " split " glycerine the still can be run for a fortnight without being cleared. The " bottoms " in this case are also of a tarry nature. They are, however, free from salt, and are employed to some extent in the manufacture of such commodities as boot blacking.

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